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Ecosystem Regulatory Services and Human Comfort in an Outdoor Environment of Lokoja, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author OOI designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript and managed literature searches. Authors PAE, TIO managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aims: To determine the effect of land cover change and local temperature variation on the thermal comfort of inhabitants of the town while carrying out their outdoor activities.
Study Design: Application of satellite imageries, meteorological data and questionnaire for the study.
Place and Duration of Study: Department of Geography and Planning, Kofi State University, Antigua, Nigeria between June and October, 2012.
Methodology: Computation of 12 months humidor values from temperature and humidity data for the year 1987, 2001 and 2011. Satellite image processing, classification, victimization and interpretation for land use and land cover change for 1987, 2001 and 2012; extraction of NDVI values and map for 2012 using Arc GIS 9.2. Land use and Land cover change rate were calculated. Temporary installation of thermo-hygrometers in 10 identified neighborhoods for a daily humidor values for the months of July, August and September 383 copies of questionnaire was retrieved and analyses using principal component analysis method of SPPS 17 software.
Results: The least humidor values of 34.7 in December 1987, 34.4 in January 2001 and 35.8 in December 2011 indicated that discomfort is a common feature. The increasing change in rate in built up (0.95km2/yr) and the corresponding decline in rate of vegetation

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(1.73km2/yr) is the responsible for the near dryness in the built up area indicated by the NDVI values are attest to the increasing level of discomfort in the area of study. The perception level is significant s the KMO value of 0.602 which suggest a strong positive correlation among the variables. Effect of Land and sea breezes accounted for 22.7% of the variation in discomfort, urbanization 16.4% and Exposure 10%, while improper mitigation processes accounted for 8.8% and 11.4% for health implication.
Conclusion: The rapid response to urban green economy will enhance the proper benefits of ecosystem services to Lakota environment. The governmental and non-governmental agencies are sensitize the general public on the role of vegetation in the environment, as this contribute to regulating air temperature.

Keywords: Ecosystem services; thermal comfort; outdoor activities; temperature; humidity; humidor.

1. INTRODUCTION

Humanity has always depended on the services provided by the biosphere and its ecosystems. The extraordinary variety of ecosystems, species and genes that surround us, is our life insurance, giving us food, fresh water and clean air, shelter and medicine, mitigating natural disasters, pests and diseases and contributes to regulating the climate. Ecosystem services are the benefits people obtain from ecosystems [1]. These services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life. Asides the production of food, ecosystem system services are the actual life-support functions, such as cleansing, recycling, and renewal, and they confer many intangible aesthetic and cultural benefits as well [2].

Ecosystem services have declined more rapidly over the past 50 years than any other period in human history. The increasing concern over the global disappearance of ecosystems suggests that important services are lost as a consequence to the detriment of human welfare [3]. Driven mainly by human activities, the current rates of disappearance of ecosystem services are incomparable to the rates at which they are replenished [4].

During the last decade, interest in the assessment of thermal comfort has increased considerably because of climate changes and increased heat stress in cities. However, there have been relatively fewer studies on thermal comfort for outdoor environment [5,6,7,8], even though many have been done on thermal comfort especially for indoor environment. The difficulty in assessing outdoor thermal conditions is that the climatic variables are much more diverse than in indoor settings. However, the importance of outdoor thermal comfort studies is increasingly recognized with changing climate and increased heat stress in cities [9]. Empirical relations and observations, based on relative outdoor thermal comfort expressed by human subjects under differing atmospheric conditions, have attempted to indicate the temperature at which air, at some standard humidity, air motion and radiation load would be equally uncomfortable or comfortable [10].

Today's urbanized towns and cities, including Lokoja in Nigeria, comprise asphalt roads, concrete pavements, Modern markets, parking lots, buildings and because these surfaces are quite dark, they absorb most of the visible light that falls on them and as a result, the absorbed solar energy heats up the pavement. In turn, the air is heated by the pavement and certain areas and surfaces over theses cities are warmer than their surroundings, leading to differing perceived air temperature and this phenomenon is known as urban heat island (UHI) effect [11]. The study however places human thermal comfort as the central focus for assessment, while recognizing that disappearance of ecosystem regulatory services (particularly loss of vegetation) has intrinsic consequences on Human welfare. A dynamic interaction exists between people and ecosystems, with the change in Human thermal comfort, in most cases, resulting from derived change in ecosystems services i.e. with changes in vegetal cover, causing changes in human thermal comfort. Although many other factors, independent of the environment, change human condition, and many natural forces are influencing ecosystems as well. Most cities are sources of heat and pollution and the thermal structure of the atmosphere above them is affected by the so-called "*heat island effect"* [12]. The heat that is absorbed during the day by the buildings, roads and other constructions in an urban area is re-emitted after sunset, creating high temperature differences between urban and rural areas [13].

The research focuses particular attention on the linkages between certain ecosystem services and human well-being. The study aims at determining the effect of land cover change and local temperature variation on the thermal comfort of inhabitants of the town while carrying out their outdoor daily activities.

2. MATERIALS AND METHODS

2.1 Study Area

Lakota lies between Latitudes 7º 45N-7º 51N and Longitudes 6º 41E-6º 45E, and located in Lokoja Local Government Area of Kogi State. It is situated at the confluence of Rivers Niger and Benue in Kogi state, Nigeria (Fig. 1). The town falls within the tropical savannah climate and the Koppen - AW climatic group. The wet season starts from May till October and the dry season from November till April. The highest temperature of 36.7ºC occurs in March while the lowest temperature of 30.8ºC occurs in July at the peak of rainy season. This indicates the hotness throughout the year in Lokoja. The averaged total rainfall received is 1158.9mm, in which the highest concentration of rains is in the month of June and September. Relative humidity is highest through the raining months with a mean value of 82.2% and 61.1% during the dry season. The apparent presence of the confluence of the Rivers Niger and Benue has made Lokoja a prime location for future part of activities to the northern part of Nigeria. It is arguably the fastest growing town in kogi state and the seat of Government. It was declared by the 2006 census to have a population of 81,673 [14].

2.2 Meteorological Measurements and Calculations

A three epoch (1987, 2001 and 2011) minimum and maximum temperatures and relative humidity were collected from the Nigerian Meteorological (NIMET) Station in Lokoja. The researchers used ten (10) thermo-hygrometers to retrieve current air temperature data to support the questionnaire administered. To describe the thermal perceptions of the inhabitants, eleven weeks diurnal air temperature data and monthly relative air humidity (RH, %) data were obtained. Ten (10) neighborhoods were identified and makeshift base stations (height of 2m at street level) were established (Fig. 2) in each neighborhood to collect maximum and minimum temperatures and relative humidity directly for the period of study (July, August and September). Both categories of data were used in the determination of thermal comfort of occupants of Lokoja town as these figures were imputed into the humidex calculator to determine humidex values of inhabitants of the different neighborhoods.

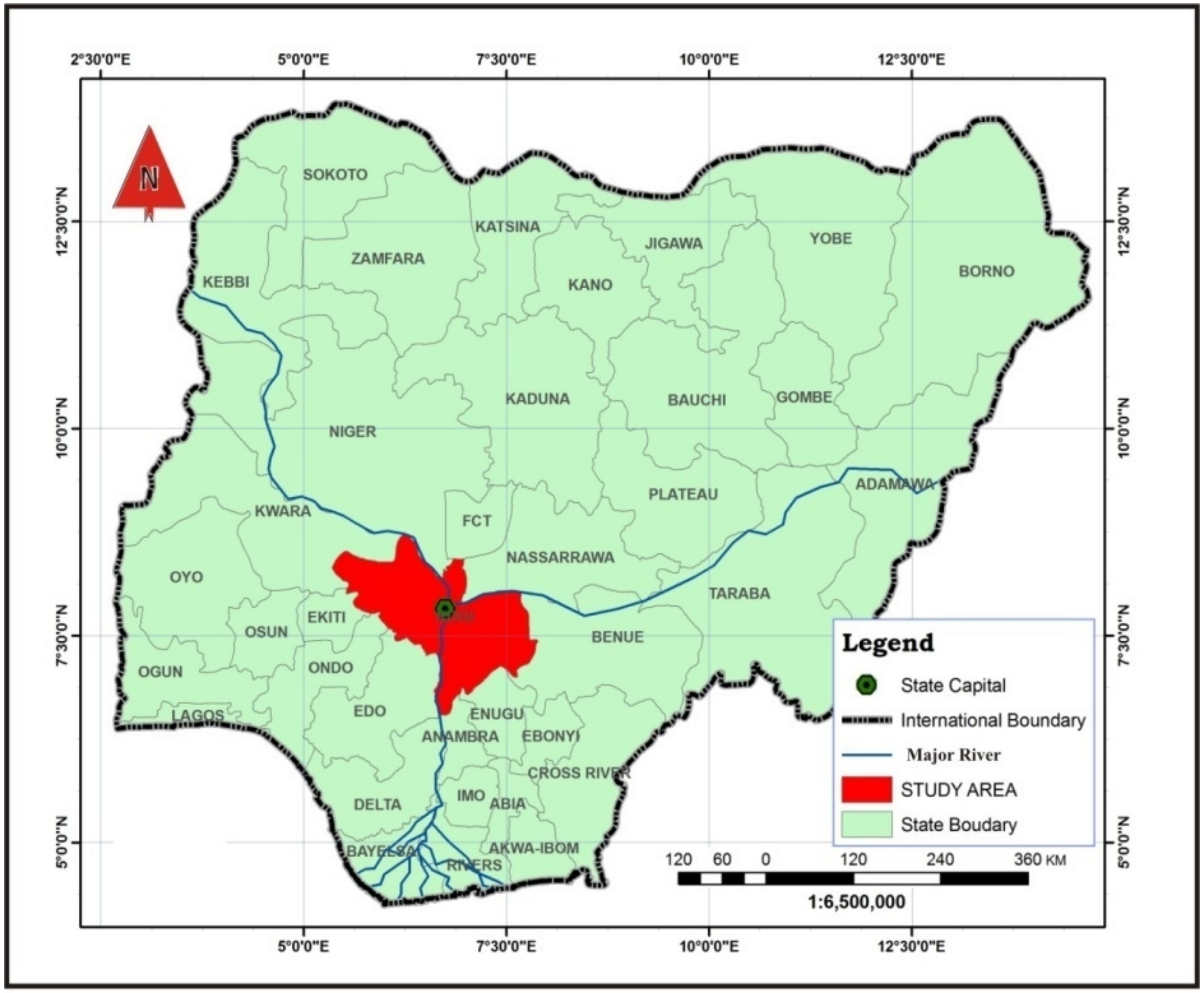

Fig. 1. Nigeria showing Kogi state

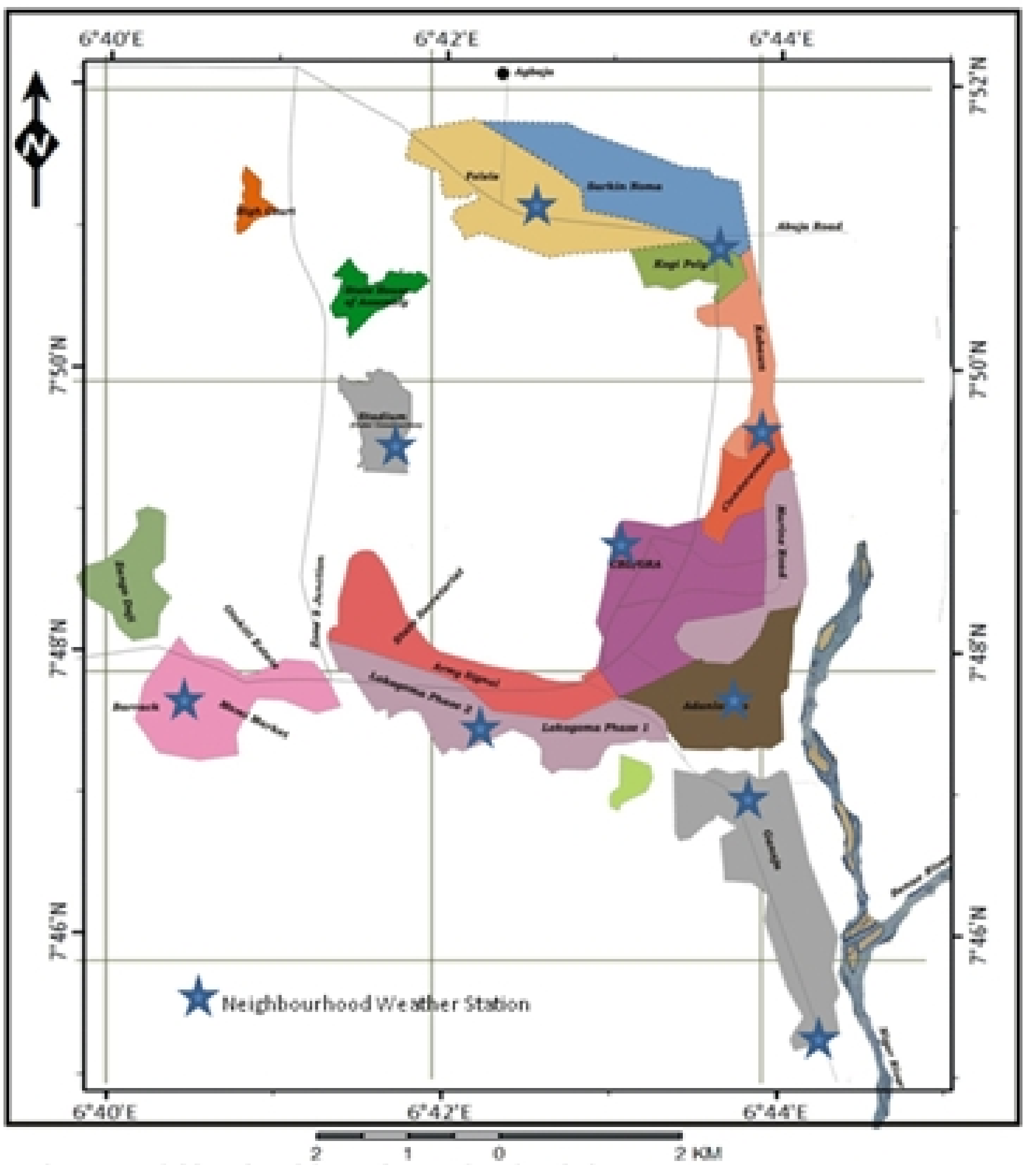

Fig. 2. Neighbourhoods' weather stations in Lokoja town

The humidex values are equivalent temperature (one that human body would feel) given the actual temperature and relative humidity of air. The humidex formula is based on the work of J.M masterson and F.A. Richardson, 1979. It is a standard for Canada but variations are around the world. The formula is given as follows.

$$H=T+ (0.5555* (E-10) \qquad (1)$$

Where H=Humidex
T=temperature (0 C)
E=relative humidity

The interpretation of the calculated humidex values were done using the Canadian Meteorologist table (Fig. 3)

Fig. 3. Interpretation of the calculated humidex values of inhabitants
Source: Adapted from Canadian meteorologists (1965)

2.3 Digital Image Classification, Integration and Analysis

Based on a reconnaissance survey with additional information from previous research in the study area, all pixels were classified into one of six surface types using the supervised maximum likelihood classifier algorithm of ILWIS 3.3 Academia GIS software. Several training sites were selected as supervisors for each surface type. The six types of surface condition were named according to each representative feature. Further calculation of changes and conversion of the resulting land use/land cover types from meter square to kilometer square for each of the years were done. The classified land use images were further vectorized and built up area and vegetation distributions were extracted for the purpose of the study. This was particularly done to compare lose of vegetation and increase in built area individually over the years. Due to the integrated data processing within arc map, it was possible to select and extract these data sets (vegetation and built up area) between imageries of 1987 and 2012. The rate of change for each land use land covers for the period of years covered were estimated.

Normalized Difference Vegetation Index was created for the study area mainly to represent the current condition of vegetation in Lokoja. As an addition to the data sets retrieved from image classification, NDVI was carried out for this study since it is one of the most powerful and most applied indices of vegetation.

2.4 Questionnaire Administration

A total of 408 copies of questionnaire were purposively administered to residents in the ten (10) neighborhoods identified and 383 copies were retrieved and used for the analysis. The questionnaire addresses how the residents of Lokoja perceive the heat threat and its mitigation.

3. RESULTS AND DISCUSSION

3.1 Interpretation of Humidex Values for 1987, 2001 and 2011

The calculated humidex values (Fig. 4) of these various years indicate that Lokoja is generally hot, but although certain months are perceived to be hotter. The trend in the calculated humidex values of these years shows that April exerts more thermal discomfort of the occupants of Lokoja. However, this is closely followed by March, May, and February. The humidex values for the various years revealed that temperature has however been on the rise, where the month of April recorded the highest humidex values, hence highest discomfort, with humidex values of 42.6 in 1987, 45.3 and 45.0 in 2001 and 2011 respectively.

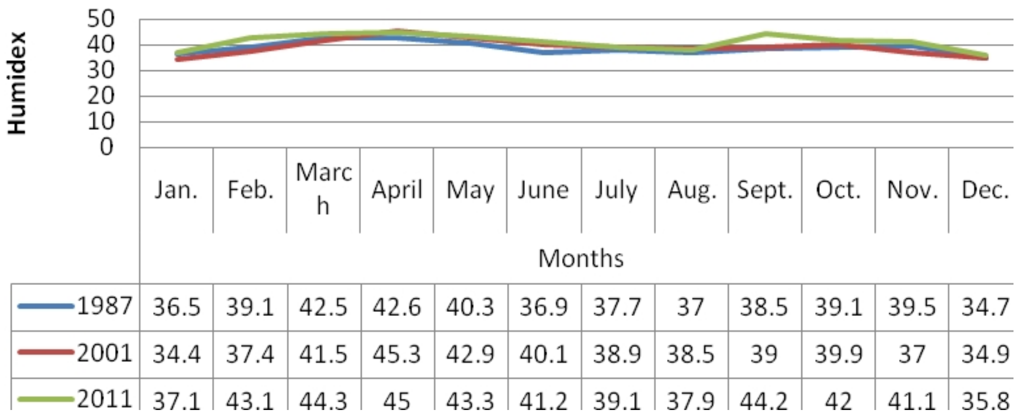

Fig. 4. Annual Lokoja Humidex values for 1987, 2001 and 2011

3.2 Image Classification and Vectorization and NDVI

It was discovered that thick vegetation covered about 50.23% of the total area in 1987 which has rapidly dropped to13.39% in 2001 and 6.85% of the area in 2012 (Table 1). Meanwhile, increase in built up area has been on the rise, from only 6.42% in 1987, 14.72% in 2001 and up to 30.04% in 2012.Such reduction and rise in both vegetation and built up area in the various years (1987, 2001 and 2012) was confirmed, based on questionnaire administered, to be due to human activities through urbanization as drawn by the respondents' perception in Table 3.

The study area covers about 166.1808 km^2 of land and out of which about 83.47km^2 was covered by thick vegetation in 1987, whereas about 45.05km^2 was covered by bare surfaces and 21.17km2 by light vegetation.

Table 1. Change in land use and land cover (LU/LC) types in Lokoja

LULC types	Change in LULC (KM^2)			Rate of change (KM^2/YR)		
	1987	2001	2012	1987-2001	2001-2012	1987-2012
Built up area	10.66	24.46	49.92	0.6	1.4	0.95
Thick vegetation	83.47	22.25	11.38	-2.6	-0.6	-1.7
Light vegetation	21.17	104.64	76.67	3.6	-1.5	1.336
Vacant land	45.05	6.32	21.78	-1.6	0.8	-0.56
Water body	5.31	7.51	5.81	0.1	0.01	0
Outcrop rock	0.00	0.38	0.53	0.02	0.006	0.01
Total	166.1808	166.1808	166.1808			

Source: Authors' Work, 2012.

The vectorized vegetation distribution of the study area which compares the rapid drop in vegetation distribution between 1987 and 2012 (Fig. 5), confirms the high rate of land use conversion to developed land uses and the impact that man's activity has had on the area where thick vegetation which covered 83.47Km^2 of land in 1987, rapidly dropping to 22.25km^2 by 2001 with a change rate of 2.6km^2/yr.

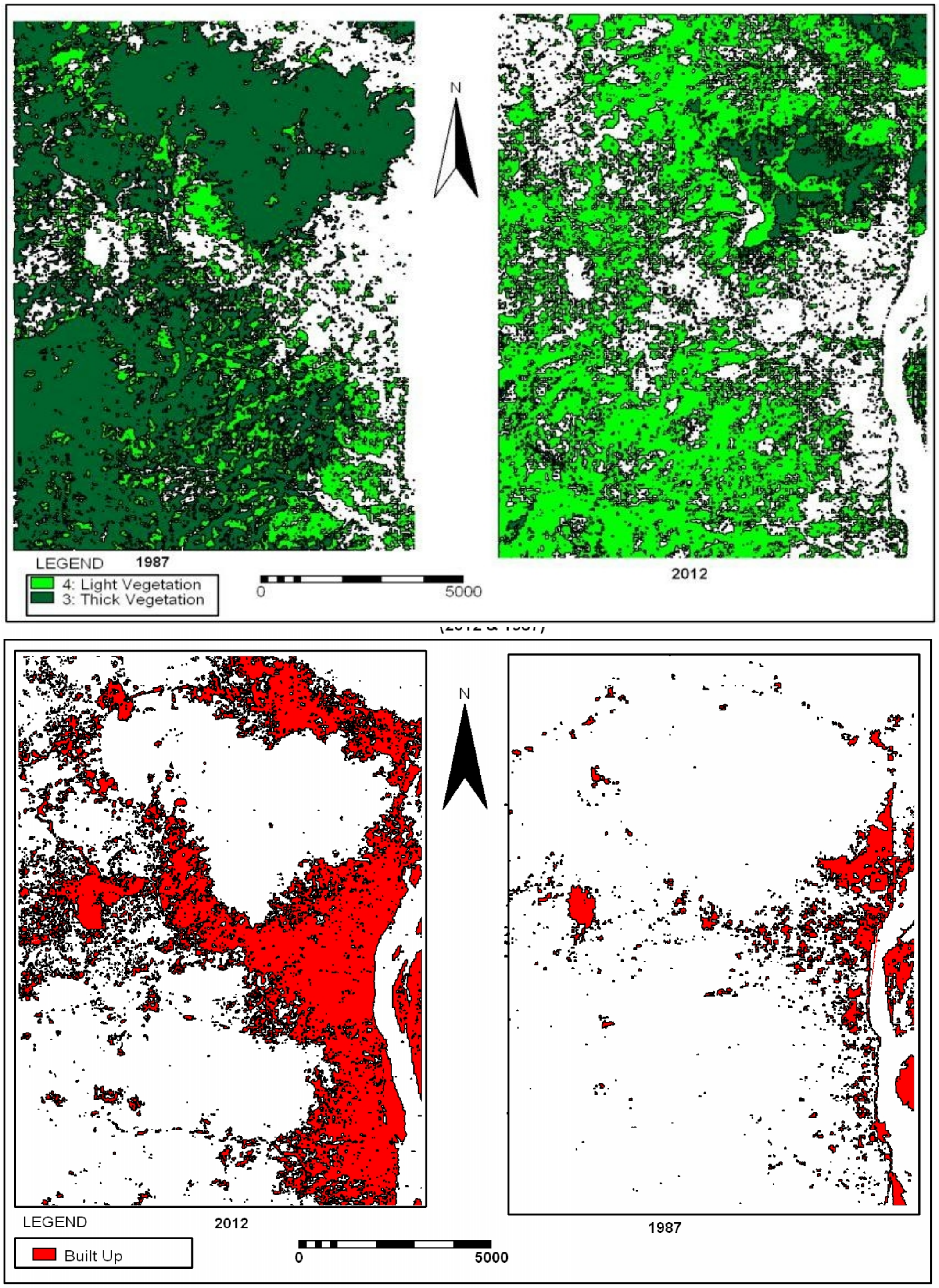

Fig. 5. Vectorized built-up and vegetation distribution for 1987 and 2012
Source: Authors, work, 2012

On the contrary, built up area which covered only 10.66 km^2 of land (6.41%) in 1987 had more than doubled by 2001 with an area of 24.46 km^2 (14.72%). By 2012, built up distribution had rapidly covered about 49.92 km^2 (30.04%) of land mass of the total area. This however is directly related to urbanization in the area since more and more people who are migrating would require shelter and space as they engage in one socioeconomic activity or the other and also in the conversion of vegetation into both built up and vacant land uses. Fig. 6 shows that built up area falls within the NDVI value of 0.00 to -0.25. This indicates that dryness and near impervious and tar surfaces within the land use.

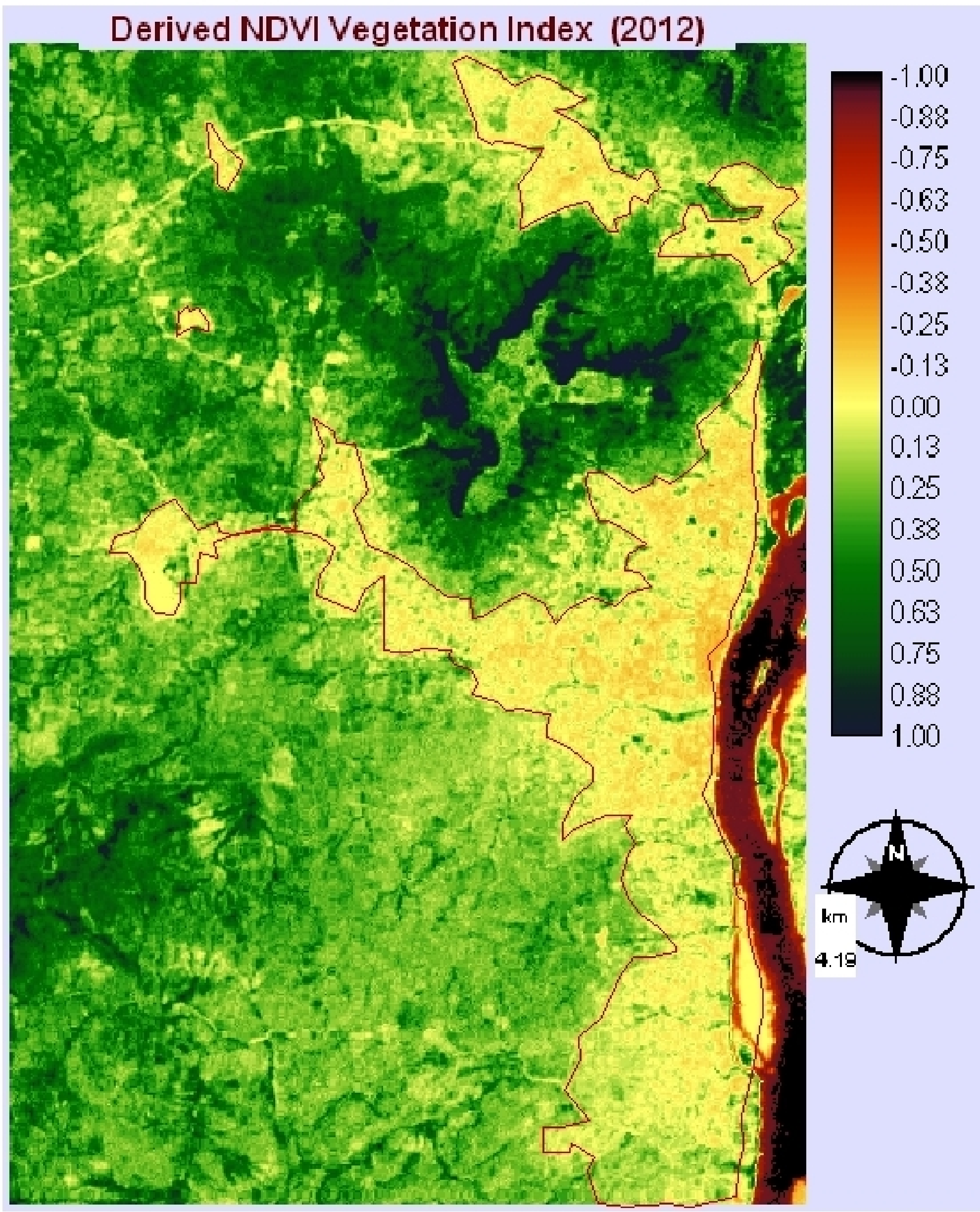

Fig. 6. 2012 NDVI Map of Lokoja

The trend between mans' activities, Ecosystem regulatory services as well as human comfort in Lokoja town may pose a complex situation through their interaction at multiple temporal and spatial scales, especially in congested areas of Kabawa and cantonment, as well as areas of Ganaja junction, Adankolo, and Lokongoma which recorded high humidex values from July to mid September 2012 (Fig. 7). The least humidex value of 38 (some discomfort) in the month of July in Kabawa and Otokiti indicate the spatial scale of discomfort across the neighborhoods. As such, the harsh micro-climate condition of these areas may have resulted from changing land cover and use, while changes in thermal comfort may have in turn, resulted from the climate variability and the urban heat island effect [14].

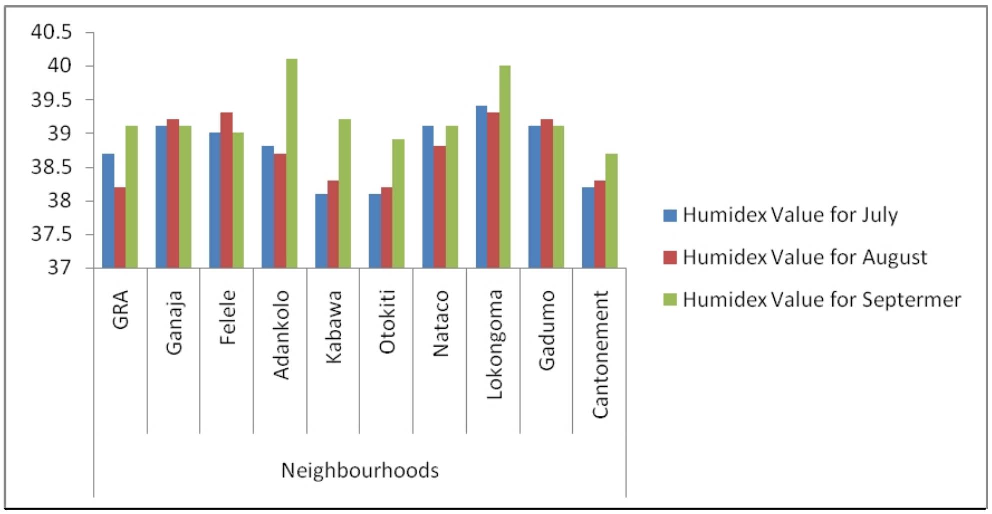

Fig. 7. 2012 Three months Pattern of humidex value in Lokoja town
Source: *Authors' Work, 2012.*

3.3 Lokoja Residents Perception of Thermal Comfort

3.3.1 Factor analysis

Barlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy confirmed that there was sufficient correlation among the perception variables to warrant the application of factor analysis (Table 2).

Table 2. KMO and Bartlett's test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.602
Bartlett's Test of Sphericity	Approx. Chi-Square	1606.812
	df	171
	Sig.	.000

Principal component analysis was applied to extract main features of the responses from 19 variables (responses) (Table 3). The component patterns were simplified through a Varimax rotation. In all, six (6) components were extracted.

Table 3. Rotated component matrix (a)

Residents' Responses	Component					
	1	2	3	4	5	6
Rivers have significant impact on the thermal comfort	.831					
Most outdoor activities are done for over 10 hours	.764			-.314		.302
Water intake of inhabitants ranges from 2-3 times every hour	.732					
Poor planning of layouts may have resulted to congestion of buildings and poor ventilation	.724	.364				
Most occupants wear light weight or cotton cloths	.529			.330		.427
Decrease in vegetation and increase in built up area due to urbanization		.781				
Spatial variation of temperature across the neighborhoods		.769				
Lokoja has rapidly grown over the years in terms of population and area size		.671		-.313		-.342
Increase in temperature over years noticeable	-.321	.627				
Increase in population of Lokoja has brought about a reduction in vegetation distribution as well as increase in temperature	.375	.598				
Increase and variation in temperature has influenced the distribution of different perception of thermal comfort	-.306	.488	.455			
Activities carried out either standing or walking			.821			
Both arms and/or the whole body are used in outdoor activities			.810			
Decision Makers should adopt the concept of green economy				.802		
Urban renewal, planting of urban trees and creation of open spaces may improve thermal comfort of inhabitants				.700	.315	
Inhabitants drink water most often as a result of dehydration					.841	
Dehydration of inhabitants may result in increased heat stress			.369		.668	
Application of serious physical strength in most outdoor activities						.692
Most health problems of inhabitants are heat stress			.363	-.340		.513
Proportion of Total variance (%)	22.7	16.4	10	8.8	5.8	5.6

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 10 iterations

These six (6) components are defined as follows: Component 1 – Effect of Land and Sea Breezes, Component 2 – Effect of Urbanization, Component 3 – Exposure, Component 4 -

Mitigation, Component 5 and 6 are Health implication. At a lower cut limit of .600, responses were chosen to reflects the defined components.

3.1.1.1 Effect of land and sea breezes

The Impact of Rivers on Thermal Comfort (+0.831) and congestion of building and poor ventilation (+0.724) accounted for 22.7% of total variance within the data set. All these variables contributed to about 22.7% of the variation caused by land sea breezes

3.1.1.2 Effect of Urbanization

The decrease in vegetation and increase in built-up (+0.781), spatial variation of temperature across the neighbourhoods (+0.769), rapid growth of Lokoja in terms of population and land mass area (+0.671) and the increase in temperature over the years (+0.627) are all components of urbanization contributed 16.4% of the spatial variation.

3.1.1.3 Exposure

Livelihood outdoor activities involving arms and/or the whole body (+0.821) either done standing or while walking (+0.810) is so coming among informal sector of the economy. It account for the 10% of the variation.

3.1.1.4 Mitigation

The non adoption of green economy (+0.802), urban renewal, planting of trees and maintaining the available open spaces (+0.700) within the town as strongly suggested by the respondents to improve the thermal comfort of respondents accounted for 8.8%.

3.1.1.5 Health Implication

The serious physical strength been applied in most outdoor activities (+0.692) results in inhabitants drinking water most often to stop been dehydrated (+0.841). As dehydration result into increased heat stress (+0.668) among inhabitants.

It was observed that sea breezes from the River Niger as becomes natural cooling source in improving the urban thermal environment, but the presence of several buildings and hilly ground such as The Patti Ridge prevent sea breeze from reaching the inner areas and warmer parts of the town as reported in Malaysia [14]. This suggests why there are spatial variations of temperature across the neighbourhoods. The buildings' architecture, urban planning, density of population and urban thermal environment all have important effect on out-door comfort condition as reveal by the study. As reported, land use characteristics such as morphology of the urban landscape and presence of impervious surfaces (Tarred and Concreted) contributed to the intensity urban thermal environment [15,16,17]. This agrees with the study similar findings [18,19].

On the contrary, land and sea breezes and vegetation are to provide cooling of the air temperature as a result of heat been emitted from the urban centre due human activities but as a result of the morphology of the urban landscape, this cooling is only witnessed by neighbourhoods at the periphery and closer to River Niger and surrounding vegetation. Therefore, the sea breeze penetration into the central business district is very much limited due to morphology and architecture of the buildings [14]. Consequently, a rapid approach to the greening of landscape within the neighbourhoods will be better and residents should avoid long exposure to outdoor activities.

4. CONCLUSION

The trend between mans' activities, Ecosystem regulatory services are as well as human comfort in Lokoja town revealed a complex situation by their interaction at multiple temporal and spatial scales, where changes in micro-climate of the town may have resulted from changing land cover and use, while changes in thermal comfort may have in turn, resulted from the climate variability. Urban heat Islands were discovered to exist within neighborhoods in Lokoja. Highest air temperatures and humidex values were recorded in areas of Kabawa, Cantonement, Adankolo and Ganaja junction. These are arguably the busiest areas in Lokoja town and were discovered to have hotter temperatures. The high rate of socioeconomic activities going on in these areas, coupled with the fact that vegetation has been totally damaged in the area, account for their hot and uncomfortable outdoor spaces. However, the rapid response of Government to the adoption and implementation of Urban Green Economy policy will usually enhance and improve the ecosystem services derived from vegetal and water bodies around the urban area. Both government and non-governmental agencies can sensitize the general public of the dire need and importance of vegetal bodies to the cooling and regulating air temperature.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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