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ASSESSING THE ENVIRONMENTAL EFFECTS OF SLUM GROWTH IN KUJE, FEDERAL CAPITAL TERRITORY

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Abstract

Slums are densely populated urban residential areas characterized by overcrowded, deteriorated, and poorly serviced housing conditions, typically inhabited by low-income populations. According to UN-Habitat (2013), slums are marked by inadequate infrastructure, poor sanitation, and limited access to basic services. Globally, the number of people living in slum settlements has continued to rise significantly, exceeding one billion, with a substantial proportion concentrated in Sub-Saharan Africa, Eastern and South-Eastern Asia, and Central and Southern Asia. Projections indicate that this figure may reach approximately two billion in the coming decades, reflecting the rapid pace of global urbanization and inequality in urban development.

In Sub-Saharan Africa, slum expansion remains a pressing concern, driven by population growth, rural-urban migration, and inadequate urban planning systems. Nigeria, like many developing countries, is experiencing a steady increase in informal settlements as cities struggle to accommodate expanding populations. These slum environments not only reflect socioeconomic deprivation but also contribute to environmental degradation and climatic challenges.

The rapid growth of slums has significant environmental consequences, including increased pollution, deforestation, poor waste management, and the destruction of natural drainage systems. These conditions contribute to localized climate impacts such as rising temperatures, flooding, and reduced environmental quality. In urban areas such as Kuje in the Federal Capital Territory, Nigeria, slum proliferation exacerbates existing environmental vulnerabilities, placing pressure on land use, infrastructure, and ecological balance.

This study examines the environmental consequences of slum growth with a focus on its climatic impacts in Kuje, Federal Capital Territory. It explores how unplanned urban expansion influences environmental sustainability and contributes to climate-related risks. The study emphasizes the need for effective urban planning, sustainable housing policies, and environmental management strategies to mitigate the adverse effects of slum development.

In conclusion, slum growth represents not only a social and economic challenge but also an environmental and climatic concern that requires urgent attention. Addressing these challenges is essential for promoting sustainable urban development and improving living conditions in rapidly growing cities.

Keywords: Slum Growth; Urbanization; Environmental Degradation; Climate Impact; Kuje Federal Capital Territory.

Introduction

A slum is usually a highly populated urban residential area consisting mostly of closely packed, decrepit housing units in a situation of deteriorated or incomplete infrastructure, inhabited primarily by impoverished persons (UN-Habitat, 2013). UNPD-DESA (2011) observed that the absolute number of people living in slums or informal settlements grew to over 1 billion, with 80% attributed to three regions; Eastern and SouthEastern Asia (370 million), Sub-Saharan Africa (238 million) and Central and Southern Asia (227 million). In the sub-Saharan Africa's projection, it was estimated that in the next thirty years, the global number of slum dwellers would have increased to about two billion. In the developing, informal or slum settlements are absorbing an increasing number of the expanding urban population and are home to the vast majority of the urban poor (World Bank, 2019). In some cities in developing countries, slums are so pervasive that it is the rich who segregate themselves behind small gated enclaves. In the developing countries the number of slum dwellers was estimated to be 1.43 billion by 2020 (Middel *et al.,* 2022). Slum formation in Nigeria and in Africa is on the increase as the world rapidly urbanizes (Adewale, 2019).

The urbanisation rate in Nigeria is 5.5%, almost twice the population growth rate of the country (Adewale, 2019) and this comes with the growth of slums. The development out of Abuja as the Federal Capital Territory of Nigeria 40 years ago which led to the development of the city, is now having emerging slum problem. Most of the slums are not far away from the city centres with a substantial number of people residing. As a result of housing deficit in the Nigeria capital city, many people live in slums but work in the Abuja city.

Largely local climate is determined by location and exposure of the area and surface conditions such as heat capacity, moisture content, vegetation cover, albedo and roughness of the ground surface (Babatola, 2013; Huimin *et al.,* 2021). A major cooling factor in a natural environment is the evapo-transpiration process, which occurs in areas with vegetation and access to water and acts cooling due to the energy consumed in the process. Reduction of natural vegetation in an area lessen the possibilities for the evapo-transpiration process and thereby possibly reduces the natural cooling effect where vegetation is scarce (Babatola, 2013). Due to paved surfaces and growing structures urban slum areas have a much faster run-off of excessive water, which may further reduce the natural cooling due to the shorter time the water is available for evaporation (Huimin, *et al.,* 2021).

Over the years, the link between urban sprawl and climate change has gained global attention in recent decades due to high rise in urban population (Saghir & Santoro, 2018; Feng & Gauthier, 2021). Urban slum growth leads to distortion in surface temperature, wind speed, humidity, rainfall and surface soil moisture. Urban thermal environment dynamics were associated with land use and land cover (LULC) changes as well as seasonal variations (Xueqin *et al.,* 2022). Urban slums are particularly more vulnerable to changing climatic elements due to their high poverty level (IPCC, 2022). Remote sensing provides various data for investigating urban structures, land cover, and biophysical characteristics (Middel *et al.,* 2022). These urban characteristics are extremely important in understanding the urban thermal environment, especially the relationships between LULC and vegetation indices (Xueqin *et al.,* 2022). Existing remote sensing-based data enable the investigation of temporal and spatial patterns, as well as thermal characteristics, although observations in specific areas can remain challenging. In recent years, studies on urban land use/land covers changes abound but studies that characterize and assesses climatic variables under different land use/land cover are lacking except LST studies. Studies with geospatial techniques in assessing urban expansion, sprawls and slums in Nigeria include the studies of Ishaya *et al*. (2008), Opeyemi *et al.* (2015), Akpu *et al.* (2017), Williams and Innocent (2017), Mbaya *et al.* (2019), Wizor *et al.* (2020) and other studies evaluate slums development and their effects on inhabitant's environment and living conditions (Ayeni *et al.,* 2019). Adepoju *et. al.* (2013) attempted mapping and monitoring of slum development in Abuja using remotely sensed imageries and geographical information system but the temporal scope was between 2005 to 2012 in the FCT. Other researchers (Babatola, 2013; Yitong *et al.,* 2015; Chapman *et al.,* 2017; Huimin *et al.,* 2021; Kwasi *et al.,* 2022; Xueqin *et al.,* 2022; Bei *et al.,* 2019; Xiaolin *et al.,* 2022) applied remote sensing and GIS first in classifying land use/land cover and subsequently assessed climatic variables under the classified land use/land cover. Despite wide coverage of such researches no study was identified that assessed urban slum growth impact on climatic elements under different land use/land cover in Kuje urban area of the Federal Capital Territory of Nigeria.

Study Area

The study area (Kuje slum) is located within Kuje town which is the headquarters of Kuje Area Council that lies between latitude $8^0$27'43" to 8^0 56'32"' North of the equator and longitude 6^0 58'13" to $7^0$33'11" East (Figure 1) while the urban slum in cover 609.066 hectares (Figure 2). The Kuje slum area is void of vegetation with distinct wet and dry season climatic condition. The wet season falls between the months of April to October while dry season is between November and March with average rainfall of 1555mm and mean temperature during the dry season ranges between 30.4 and 35.1^0C while the temperature ranges between 25.8 and 30.2^0C in the raining season (Ishaya & Mashi, 2008).

At the fringes of the town, the suitability of the soil for agriculture influenced the major economic activity in the study area which is farming. The major ethnic groups are the Gbagyi and Gwandara who are mostly farmers engaged in farming of yams, cassava, cocoyam, sweet potatoes, groundnuts, rice, maize, guinea corn, rice, melon. Cat fish farming, cattle are reared by the nomadic Fulanis, sheep, goats and poultry are kept mostly on free range system mostly by other tribes other than the Gbagyi and Gwandaras who have come to settle there. Due to its proximity to the city, Kuje town has been experiencing rapid expansion buildings and spontaneous increase in human activities over the years as the population continued to increase in the area, the urban renewal exercise witnessed between 2003 and 2005 has forced many people to settle in the satellite towns of Kuje, Gwagwalada, Kubwa, Zuba and Bwari which is one of the major causes of slums growth in the satellites towns in the FCT (Ishaya & Hassan, 2013).

Research Methodology

Multi-Criteria Remote Sensing, GIS techniques and quantitative research design were adopted in this study. The output of the multi-criteria Remote Sensing, GIS techniques design was for the land use/land cover and change detection of the Kuje Urban slum. The quantitative design allowed the manipulation of temporal temperature, surface soil wetness and relative humidity data to ascertain trend and anomalies under different land use/land cover in the Kuje Urban slum.

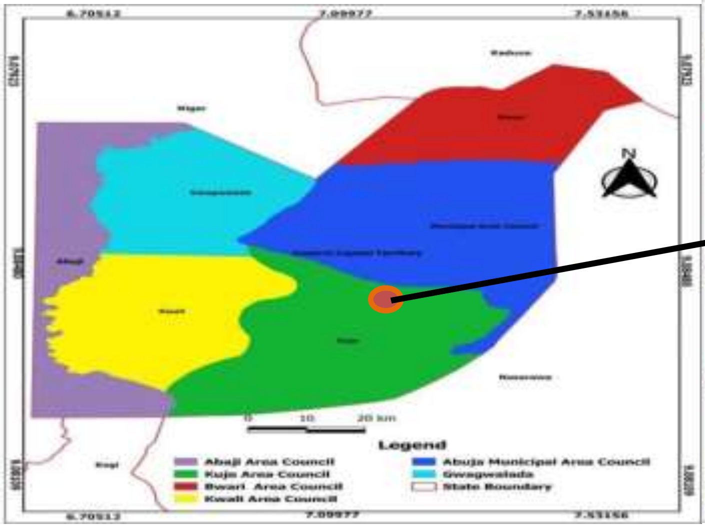


Figure 1: Area Councils in the FCT Figure 2: Image of Kuje Town Showing Slum Area

Table 1: Satellite Images Utilized

S/N	Data	Type	Year	Format	Resolution	Source	Relevance
i	Delineated slum boundary	Secondary		Shape file		Field observation and Google Earth	To define the spatial boundary
ii	Moderate resolution aerial imagery	Secondary	2002 & 2012	TIFF	30m	Google Earth Pro	For object-based image analysis
iii	High resolution aerial imagery	Secondary	2022	TIFF	0.5m	SAS Planet	For image classification analysis

Source: Researchers Compilation, 2023

Data used

Moderate satellite images of the study area were obtained from Google Earth Pro for period of 2002 and 2012, and the high-resolution satellite image was acquired from SAS Planet for the period of 2022 (See Table 1). Location data for verification of Land use/Land cover characteristics were sourced using hand held GPS 60cx. Climatic data (earth surface temperature, relative humidity and surface soil wetness) from different land use/land cover (vegetation, slum built up area and bare surface) in Kuje urban slum was obtained from the National Centres for Environmental Prediction (NCEP) Climate Forecast System Reanalysis

Method of data analysis

Pre-processing of satellite image

Object based image analysis was used in obtaining a remotely sensed data via satellite feeds, the process involves launching of the Google Earth Pro software, navigated to the area of interest, the north arrow toggle was aligned to fitting the satellite imagery to be time for historical imageries, afterward the four point were indicated on the four-cardinal point of the imageries using point tool and their ground coordinate points were obtained to enable geo-referencing. The satellite imageries were saved and map option was adjusted and maximum resolution was selected, and save image to download to the satellite imagery

Four geographic coordinates were obtained in the study area for geo-referencing the Kuje urban slum. Image pre-processing involved image geometric correction to normalize the imageries as expected for classification from sensors and image enhancement was for ratification during pre-processing which includes the resolution of the spectral bands of the imagery, year of acquisition, the features shown, data evaluation and georeferencing and the projection of the imagery itself for the imageries were used in this study.

Land use/land cover analysis

Three bands' combinations of 4, 3, 2 (Red, Green and Blue bands) were used for all the imageries. This study adopted the supervised classification method that uses the spectral signatures obtained from training samples to classify an image. With the aid of ground truth, a signature file was created by training samples cells, which was used for the multivariate classification tools to classify the image (See Table 3).

Table 3: Land Use/Land Cover Classes considered

Classes	Description
Bare Surface	Fallow fields/Lands
Slum Built-up areas	Paved surfaces, settlements, developed infrastructures and tarred roads
Agricultural Land Use	This include cultivated fields
Vegetation cover	Vegetation, in form of trees, shrubs of different height and density

Source: Researchers Generated Classification Schemes, 2023

The results of the land use/land cover types were produced in hectares to enable evaluation of land use/land cover changes. The statistical results were generated using version 15 of ERDAS Imagine software. The land use/land cover statistics were extracted using ArcGIS 10.1 while assessment of changes over the four satellite epochs were carried out from one class to the other. Using the land use/land cover maps, the change magnitude, change trend and annual rate change were generated using the formulas thus;

Magnitude = Magnitude of the new year - Magnitude of the previous year……… 1

The percentage change for each land use/land cover classes were calculated by dividing magnitude change by sum of the observed changes between the years concerned and multiplied by 100 as presented in the equation thus:

Trend =

$Magnitude\ of\ Change\ x\ 100$

$\underline{\hspace{4cm}} \dots Equation\ 2$

$Sum\ of\ Change$

In ascertaining the annual rate of land use/land cover classes, the trend multiply by number of study years divided by 100o periods, for example 1988 – 1998, 1998-2008 as shown in equation:

Annual Rate of Change =

Trend × number of study years in between

$\underline{\hspace{6cm}} \dots \dots Equation\ 3$

100

Graphs representing spectral signatures for each of the land use/land cover characteristics were generated and plotted using the statistical results of classified imageries of the three studied years.

Method of climatic data analysis

Several statistical techniques were used in analysing the climatic data (earth surface temperature, relative humidity and surface soil wetness). The preparatory level of the secondary data analysis involved simple statistical computation of totals, means, and standard deviation of earth surface temperature, relative humidity and surface soil wetness from the land use/land cover from Kuje urban slum. The earth surface temperature, relative humidity and surface soil wetness from the land use/land cover data from Kuje urban slum were subjected to time series analysis. Time series analysis is the arrangement of statistical data in respect to the time of occurrence. This was shown in line graph as it does remain the most popular method of time series presentation. This study adopted the line graph because it helps explain the nature of fluctuation of rainfall characteristics in the study area over years. The data on rainfall were plotted on the y-axis and the time (years 2002-2022) were presented on the x-axis.

A simple linear regression analysis technique was used for determining trend analysis for rainfall. The formula for trend analysis is presented below: $Y=a+bx$ $b = \underline{\sum(x - x)\ (y - y)\ \dots\dots\dots\dots}$ $\underline{\text{Equation 4.}}$

$\sum (x - x)$

$a = y - bx$ Where; a = the base intercept b = the regression coefficient or slope

x = rainfall/temperature values

y = months/years Coefficient of determination (R^2) was carried for the regression result of earth surface temperature, relative humidity and surface soil wetness trend line equation from the land use/land cover from Kuje urban slum. One-Way Analysis of Variance (ANOVA) Test was used to test variation in earth surface temperature, relative humidity and surface soil wetness for the land use/land cover over the study period in Kuje Urban slum. The formula for Analysis of Variance is thus: ANOVA coefficient, F= Mean sum of squares between the groups (MSB)/ Mean squares of errors (MSE). Degrees of freedom of errors, N – k = df2 Where, N is the total number of observations throughout k groups.

$$F = \frac{MST}{MSE}$$

$$MST = \frac{\sum_{i-1}^{k} (T_i^2/n_i) - G^2/n}{k-1}$$

$$MSE = \frac{\sum_{i-1}^{k} \sum_{j-1}^{n_i} Y_{ij}^2 - \sum_{i-1}^{k} (T_i^2/n_i)}{n-k}$$

………………… Equation 5

Where F is the variance ratio for the overall test, MST is the mean square due to treatments/groups (between groups), MSE is the mean square due to error (within groups, residual mean square), Y_{ij} is an observation, T_i is a group total, G is the grand total of all observations, n_i is the number in group i and n is the total number of observations.

Hypotheses

Two hypotheses were tested at 0.05 Alpha level. These hypotheses are;

i. Ho: There is no significant changes/variation in land use/land cover classes over the study period.

ii. Ho: There is no significant variation in the characteristics of climatic elements (earth surface temperature, relative humidity and surface soil moisture) over the land use/land cover (vegetation, agricultural land, bare surface and slum built up area in Kuje urban area between 2002-2022.

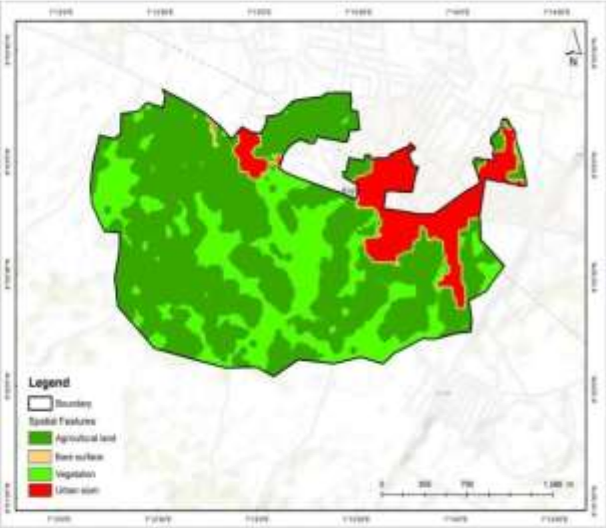
Results and Discussion

In line with the objectives of this study, the results are presented into two sections. The first presentation and discussion of results is on Kuje urban slum land use/land cover categorization and change detection from 2002 to 2022. The second objective is on Kuje slum land use/land cover climatic elements characterization from 2002 to 2022.

Kuje urban slum area land use/land cover categorization between 2002-2022 The categorization of slum land cover/land uses (agricultural land, bare surface, vegetation and residential buildings) in the Kuje urban slum area (Kayarda Kuje and Central Pasali Kuje) of Federal Capital Territory in the year 2002 depicts that vegetation area coverage was the highest with 292.186 hectares (47.97%), agricultural land covered 220.28 hectares (36.17%), urban slum covered 78.21 hectares (12.84%) and the least was bare surface with an area coverage of 18.39 hectares (3.01%) (See Table 4 and Figure 3). In 2012, Kuje urban slum area shows that land use/land cover with the highest area coverage was agricultural land with 238.02 hectares (39.08%), built up area with 193.88 hectares (31.83%), bare surface having 166.28 hectares (27.3%) while had an area coverage of 9.99 hectares (1.64%) in the years 2012. In 2012, the dominated land use/land cover were agricultural land cover against the vegetated covered area in 2002 (See Table 4 and Figure 4). From the classified image (Figure 5 and Table 4) it was revealed that in 2022 vegetation covered an area of 1.71 hectares (0.28%) in 2022, bare surface covered an area of 11.47 hectares (1.88%), agricultural land occupied 130.18 hectares (21.37%), while built up area covered 465.7 hectares (76.46%) being the highest in 2022.

Table 4: Land use Characterization of Kuje Urban Slum from 2002 and 2022

S/N	Land Use Classes	2002 Area (Ha)	%	2012 Area (Ha)	%	2022 Area (Ha)	%
i	Agricultural land	220.28	36.17	238.02	39.08	130.18	21.37
ii	Bare surface	18.39	3.01	166.28	27.3	11.47	1.88
iii	Urban slum	78.21	12.84	193.88	31.83	465.7	76.46
iv	Vegetation	292.186	47.97	9.99	1.64	1.71	0.28
Total		**609.066**	**100**	**609.066**	**100**	**609.066**	**100**
Overall accuracy		**79%**		**71%,**		**82%, 1.2**	
Kappa accuracy		**1.12**		**1.07**			



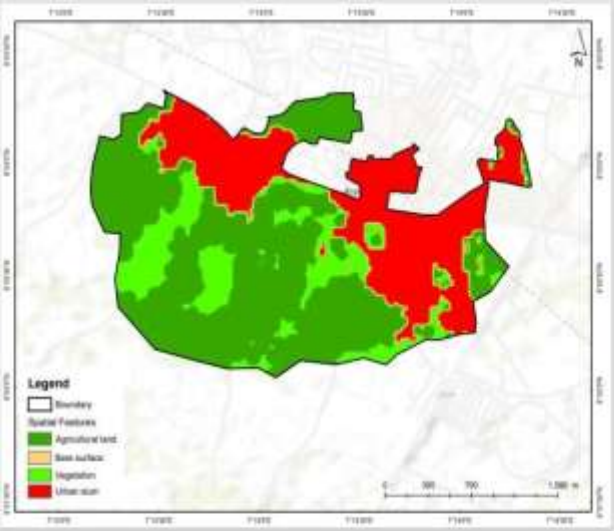


Figure 3: Classified Kuje Urban Area Slum in 2002 Figure 4: Classified Kuje Urban Area Slum in 2012

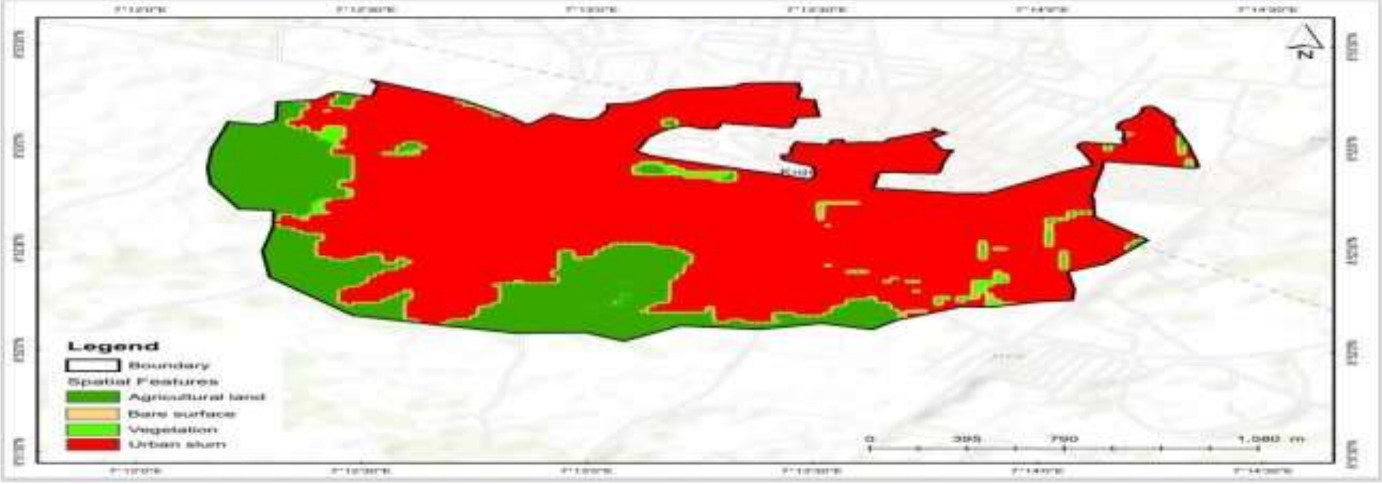


Figure 5: Classified Kuje Urban Area Slum in 2022

Slum land use/land cover changes in Kuje urban area from 2002 to 2022

Findings shows that between the year 2002 to 2012, there was an increase in agricultural land use with 17.74 hectares, bare surface increased with 147.89 hectares, urban slum area increased with 115.67 hectares while vegetation had the largest change in area with a decrease of area coverage with -282.196 hectares. Between 2002 to 2012 vegetation lands cover changed to agricultural land use, bare surface and built up land use. The large increase of bare surface area between 2002-2012 was highly related to the clearing of vegetated land for fuelwood and for slum buildings (See Figure 6). It was observed that between 2012-2022 there was a loss in agricultural land use area coverage with -107.84 hectares, bare surface declined with -154.81 hectares, vegetation land cover also declined with -8.28 hectares while there was a massive increase in urban slum area with 271.82 hectares. It was obvious that between 20122022 agricultural land use, bare surfaces and vegetal land cover were loss to urban slums (See Figure 6). The null hypothesis that state there is no significant changes in land use/land cover classes over study period clearly is in dispute as findings from this study shows a reduction in agricultural land use area, bare surface and vegetal cover but with consistent increase in the urban slum built up area as shown in Figure 6. This result coincided with findings by Qurratulain and Umair (2019), Fasona and Omojola (2004), Jibrin *et al.* (2012) and Sheriff (2021) where they observed that agricultural land and vegetal covers were loss to urban/slum growth. Rikko and Laka (2013) had similar findings in Greater Karu Urban Area where a large influx of population leading to significant dynamic changes in the growth of the settlements in the area over the past two decades which is as a result of risen cost of accommodation in the Federal Capital City of Abuja. Just as observed in this study a discontinuous spread of urban leap-frogging into other land uses and land covers, fast spreading and converting viable agricultural lands, vegetal land and Kuje slum land use/land cover climatic characterization from 2002 to 2022

The interaction between LULC and climate is complex, and it can be viewed from three dimensions. First, the interaction of LULC (more specifically vegetation) on climate LULC induce changes in climate of a region as it is a factor of climate. The interaction of climate on LULC or vegetation change in climate induced LULC change due to settlement expansion and other LULC of a place stimulates effects of local climate (Kwasi *et al.,* 2022).

Trend of Kuje slum land use/land cover earth surface temperature from 2002 to 2022

The earth surface temperature from 2002 to 2022 in Kuje slum depict that area with vegetation cover had a mean temperature value of 25.92^{0}C, maximum value of 27.41^{0}C in 2006 and minimum value of 24.59^{0}C in 2002. Agricultural land use depicts mean earth surface temperature value of 26.018^{0}C, highest mean temperature value (27.66^{0}C) was recorded in 2006 and the minimum mean temperature value recorded in 2002. Bare surface had a mean earth surface temperature value of 26.068^{0}C, the maximum value of 27.69^{0}C was recorded in the year 2006 and the minimum value (24.17^{0}C) was recorded in 2009. Observation shows that mean earth surface temperature of the built-up area within the slum is 26.265^{0}C having a maximum temperature (27.72^{0}C) recorded in 2006 and the minimum earth surface temperature (24.78^{0}C) recorded in 2009 (See Table 6 and Figure 7). From 2002-2022 within Kuje slum area, the highest mean earth surface temperature among land use/land cover was recorded at the built-up slum area with a temperature value of 26.265^{0}C followed by 26.068^{0}C with the lowest earth surface temperature recorded at vegetal covered area with 25.92^{0}C follow by 26.018^{0}C recorded within the agricultural land use area.

The trend of temperature over the different land use/land cover within Kuje slum from 2002 to 2022 shows that the vegetal land cover had temperature trend line equation of y = 0.0204x +25.697 which clearly depicts a positive trend in temperature with $R^2 = 0.0267$ (2.67%). This mean a 2.67% certainty in the predictions of rise in future skin temperature in vegetal covered area in Kuje Urban slum. Between 2002-2022, the bare surface trend of temperature over the years within Kuje slum depicts a temperature trend line equation of y = 0.0184x +25.866 which clearly depicts a positive trend in temperature with $R^2 = 0.0207$ (2.07%). This means a 2.07% certainty in the predictions of rise in future skin temperature in bare surface covered area in Kuje urban slum (See Figure 7). It was observed that between 20022020, the built-up slum land use trend of temperature over the years depicts a temperature trend line equation of y = 0.0089x +26.116 which clearly shows an insignificant positive trend in temperature with $R^2 = 0.0045$ (0.45%). This means a 0.45% certainty in the predictions of rise in future skin temperature in built-up slum area in Kuje urban slum. From 2002-2020, the agricultural land use cover trend of temperature over the years within Kuje urban slum depicts a temperature trend line equation of y = 0.0191x +25.808 which clearly shows an insignificant positive trend in temperature with $R^2 = 0.0216$ (2.16%). This means a 2.16% certainty in the predictions of rise in future skin temperature in agricultural land use area in Kuje urban slum (See Figure 7).

As observed in Figure 7, bare surface and built-up area had the highest temperature values compared to temperature from vegetal cover and agricultural land use. This finding is not far-fetched from the findings of Kwasi *et al.* (2022) with results indicating that rapid urban sprawl in recent times has significantly undermined the local climate through land use and land cover changes. Kwasi *et al.* (2022) observed that there was strong statistical relationship between temperatureup areas ($p <0.05$), grass/shrub cover ($p < 0.04$) and all vegetation cover ($p < 0.03$). There was also strong statistical relationship between rainfall and built-up areas ($p < 0.03$), grass/shrub cover ($p < 0.04$) and all vegetation ($p <0.02$). They observed also that expansion in built up areas and reduced grass/shrub cover led to increases in temperature, rainfall and surface soil moisture.

The findings in this study is also in affirmation with that of Shahmohamadi (2015) and Chapman (2017) where the studies observed that urban growth was found to have a large impact on local temperatures, in some cases by up to 5^0C in North-east USA. Yitong *et al.* (2015), Huimin *et al.* (2021) and Karol and Jarosław (2023) also affirm temperature rise over all land use/land cover.

	y2002	y2003	y2004	y2005	y2006	y2007	y2008	y2009	y2010	y2011	y2012	y2013	y2014	y2015	y2016	y2017	y2018	y2019	y2020	y2021	y2022
Vegetation	24.59	25.73	25.95	26.77	27.41	26.62	25.54	24.65	25.26	25.4	24.95	25.43	25.7	26.65	27.09	26.39	25.93	26.3	26.68	25.46	25.84
Agricultural Land	24.64	25.78	25.98	26.88	27.66	26.73	25.64	24.67	25.37	25.47	25.25	25.52	25.78	26.68	27.45	26.41	26.03	26.35	26.70	25.49	25.89
Bare Surface	24.73	25.8	25.99	26.91	27.69	26.78	25.68	24.71	25.52	25.56	25.36	25.58	25.81	26.71	27.50	26.46	26.13	26.38	26.72	25.51	25.90
Slum Areas	24.81	25.92	26.7	26.98	27.72	26.83	25.71	24.78	25.67	25.74	27.55	25.62	25.87	26.82	27.52	26.51	26.22	26.41	26.73	25.53	25.92

Figure 7: ***Kuje Slum Land Use/Land Cover Earth Surface Temperature from 2002 to 2022***

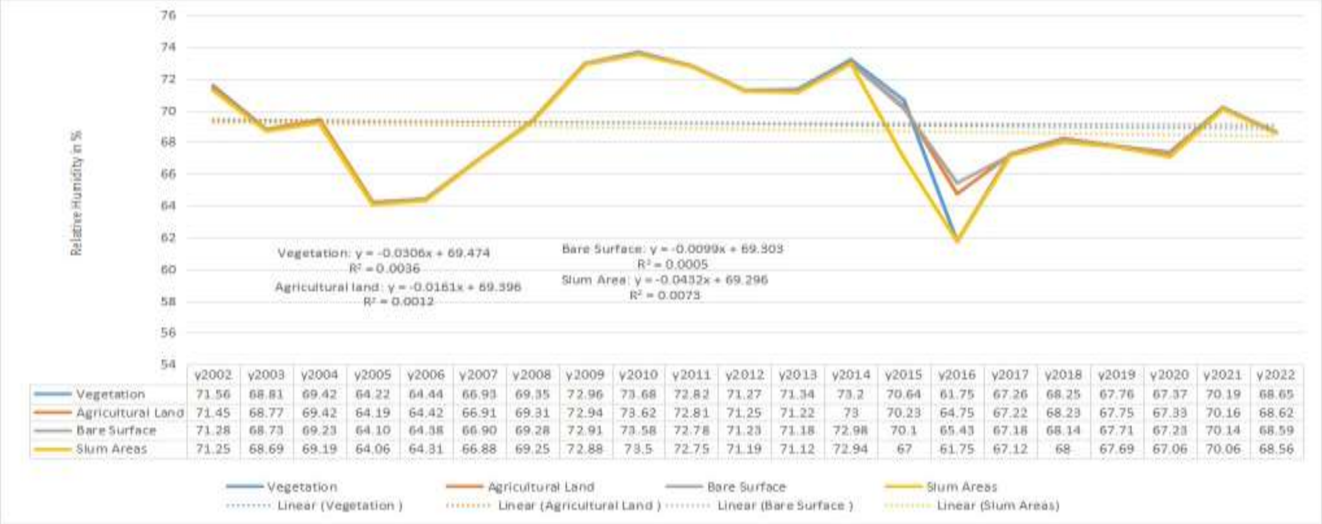
Trend of Kuje urban slum land use/land cover relative humidity from 2002 to 2022

The relative humidity from 2002 to 2022 in Kuje urban slum shows that area with vegetation cover had a mean relative humidity value of 69.14%, maximum value of 73.68% in 2010 and minimum value of 61.75% in 2002. Agricultural land use depicts mean relative humidity value of 69.22%, maximum relative humidity value of 73.62% recorded in 2010 and the minimum relative humidity value (64.19%) was recorded in 2015. Bare surface had a mean relative humidity of 69.19%, maximum relative humidity value of 73.58% in 2010 and the minimum value of relative humidity (64.1%) was recorded in 2005. In the built-up slum area, between 2002-2022 had mean relative humidity of 68.82%, maximum relative humidity of 73.5% was observed in 2010 and the minimum relative humidity value of 61.75% recorded in 2016. Between 2002-2022 within Kuje urban slum area, the highest mean relative humidity among land use/land cover was recorded at the agricultural land use cover with a value of 69.22% followed by 69.19% the value recorded on bare surface. The lowest relative humidity (68.82%) was recorded in built up slum area (See Figure 8).

The trend of relative humidity over the different land use/land cover within Kuje slum from 2002 to 2022 shows vegetal land cover relative humidity trend line equation of y = -0.0306x +69.474 which clearly depicts an insignificant negative trend in relative humidity with $R^2 = 0.0036$ (0.36%). This mean a 0.36% certainty in the predictions of decrease in relative humidity in vegetal covered area in Kuje urban slum (See Table 6 and Figure 8). Between 2002-2020, the agricultural land cover trend of relative humidity over the years within Kuje slum depicts a trend line equation of y = -0.0161x +69.396 which clearly shows an insignificant negative trend in relative with R² = 0.0012 (0.12%). This mean a 0.12% certainty in the predictions of decrease in future relative humidity in agricultural land covered area in Kuje Urban slum (See Figure 8).

It was observed that between 2002-2020, the bare surface area trend of relative humidity over the years within Kuje slum depicts a trend line equation of y = 0.0099x +69.303 which clearly portrays an insignificant negative trend in temperature with R² = 0.0005 (0.05%). This means a 0.05% certainty in the predictions of decrease in future relative humidity in bare surface area in Kuje Urban slum. From 2002-2020, the built- up slum area trend of relative humidity over the years within Kuje slum depicts a trend line equation of y = -0.0432x +69.296 which clearly portrays an insignificant negative trend in relative humidity with R² = 0.0073 (0.073%). This means a 0.073% certainty in the predictions of decrease in future relative humidity in built up slum area in Kuje urban slum (Figure 8).

It obvious that relative humidity is higher on vegetal covered areas and agricultural land used areas and slum growth negatively affects relative humidity in the Kuje slum area. Roshan, *et. al.,* (2009) also identified the relationship between urban sprawl components with changes in climate variables with depreciating relative humidity. Over the entire land use/land cover there have decrease in relative humidity all over the study period. The findings of this study affirm that of Huimin *et al.* (2021), that increase trends of temperature and built-up area indicated leads to decrease in relative humidity meaning that there is an inverse relationship between humidity earth skin temperature rise and relative humidity. Figure 8 depicts that the mean value of relative humidity from the four-land use/land cover assessed shows that relative humidity is lower in bare surface and built up slum areas but high in vegetated areas and agricultural land use areas. Though there is a general decrease in



	y2002	y2003	y2004	y2005	y2006	y2007	y2008	y2009	y2010	y2011	y2012	y2013	y2014	y2015	y2016	y2017	y2018	y2019	y2020	y2021	y2022
Vegetation	71.56	68.81	69.42	64.22	64.44	66.93	69.35	72.96	73.68	72.82	71.27	71.34	73.2	70.64	61.75	67.26	68.25	67.76	67.37	70.19	68.65
Agricultural Land	71.45	68.77	69.42	64.19	64.42	66.91	69.31	72.94	73.62	72.81	71.25	71.22	73	70.23	64.75	67.22	68.23	67.75	67.33	70.16	68.62
Bare Surface	71.28	68.73	69.23	64.10	64.38	66.90	69.28	72.91	73.58	72.78	71.23	71.18	72.98	70.1	65.43	67.18	68.14	67.71	67.23	70.14	68.59
Slum Areas	71.25	68.69	69.19	64.06	64.31	66.88	69.25	72.88	73.5	72.75	71.19	71.12	72.94	67	61.75	67.12	68	67.69	67.06	70.06	68.56

relative humidity as observed over all land use/land cover as shown in Figure 9 as observed by Roshan *et al.* (2010). Babatola (2013) also affirmed that urbanization is one serious process that transforms natural environment into various surfaces that have long run pronounced effects on the whole atmospheric system. Converting one-time thick forest surface into concrete and asphalt surfaces greatly altered aerodynamic processes in the area, water balance system as well as evapotranspiration process which reduces the concentration of relative humidity in the atmosphere in this study and Babatola (2013). In the long run, this will technically decrease trend of rainfall in the study area. Xiaolin *et al.* (2022) stated that large-scale conversion of vegetated land to urban use leads to a significant reduction in evapotranspiration (ET) hence depreciating relative humidity due to the lack of vegetation, which may aggravate relative humidity loss and Urban Dry Island (UDI) effect.

Trend of Kuje slum land use/land cover surface soil moisture from 2002 to 2022

The surface soil moisture from 2002 to 2022 in Kuje slum shows that area with vegetation cover had a mean surface soil moisture value of 0.586, maximum surface soil moisture value of 0.67 recorded in 2009 and minimum value of 0.48 recorded in 2006. Agricultural land use depicts mean surface soil moisture value of 0.575, maximum surface soil moisture value of 0.65 recorded in 2009 and the minimum surface soil moisture value (0.46) recorded in 2006. Bare surface had a mean surface soil moisture of maximum surface soil moisture value of 0.552 in 2009 and the minimum value of surface soil moisture (0.44) was recorded in 2006. In the slum built-up area between 2002-2022 had mean surface soil moisture of 0.548, maximum surface soil moisture of 0.63 was observed in 2010 and the minimum surface soil moisture value of 0.44 was recorded in 2006. From 2002-2022 within Kuje slum area, the highest mean surface soil moisture among land use/land cover was recorded at the vegetal land cover with a mean surface soil moisture value of 0.586 followed by 0.575 recorded on agricultural land use cover with the lowest surface soil moisture recorded at bare surface and built-up slum areas (See Figure 9).

As shown in Figure 9, the trend of surface soil moisture over the different land use/land cover within Kuje slum from 2002 to 2022 depicts vegetal land cover surface soil moisture trend line equation of $y = 0.0008x + 0.5771$ which clearly depicts a positive trend in surface soil moisture of $R^2 = 0.0069$ (0.69%). This means a 0.69% certainty in the predictions of insignificant rise in future surface soil moisture in vegetal covered area in Kuje Urban slum. Within the study period, the agricultural land use cover trend of surface soil moisture over the years in Kuje slum depicts a surface soil moisture trend line equation of $y = 0.001x + 0.5633$ which clearly shows an insignificant positive trend in surface with $R^2 = 0.015$ (1.50%). This means a 1.50% certainty in the predicted rise in future surface soil moisture in agricultural land use area in Kuje Urban slum (See Figure 9). It was observed that bare surface trend of surface soil moisture over the years within Kuje slum portrays a trend line equation of $y = 0.0012x + 0.539$ which clearly depicts an insignificant positive trend in surface soil moisture with $R^2 = 0.0188$ (1.88%). This means a 1.88% certainty in the predictions of rise in future surface soil moisture in bare surface covered area in Kuje Urban slum. It was observed that between 2002-2020, the built-up slum land use trend of surface soil moisture over the years depicts a trend line equation of $y = 0.0017x + 0.5297$ which clearly expressed an insignificant positive trend in surface soil moisture with $R^2 = 0.0329$ (3.29%). This means a 3.29% certainty in the predictions of rise in future surface soil moisture in built-up slum area in Kuje Urban slum (See Figure 9). It was obvious that there is less difference in the mean values of surface soil moisture, but the soil moisture is higher in vegetated area and agricultural land use area but lower at built up slum areas and bare surfaces with a significance rise in the trend of the land use/land cover in the Kuje urban slum area within the study period of 2002 to 2022. The findings agree with that of Roshan *et al.* (2009) who observed a relationship between urban sprawl components with soil atmospheric and soil moisture. The increase in surface soil moisture in vegetated area and agricultural land use area is against the findings of Xiaolin *et al.* (2022) that observed that large-scale conversion of vegetated land to urban use leads to a significant reduction in surface soil moisture over the years. The findings of this study is also agree with that of Park and Kim (2017), Syed *et al.* (2013) and Babatola (2013) who observed loss of moisture due to loss of water retention surfaces and as such intercepting water balance system on bare surface and built up areas.

Test of hypotheses of variation of climatic elements from the different land use/land cover classes over the study period

The null hypothesis of this study state that “there is no significant variation in the characteristics of climatic elements from the different land use/land cover classes over the study period was tasted at 0.05 Alpha level for earth surface temperature, relative humidity and surface soil moisture”.

The ANOVA findings expressed the variations in earth surface temperature (EST), relative humidity (RH), and surface soil moisture among the four distinct land uses (vegetation, agricultural land use, bare surface, and urban slum over a period between 2002 and 2022. Findings show that the earth's surface temperature is not significantly different across the four land uses, with an F-value of 0.689 and a p-value of 0.562. Though the mean values depict variation in the earth surface temperature, but the ANOVA result did not depict any significant variation in the earth surface temperature over the period 2002- 2022 over different land use/land cover (Vegetal cover, agricultural land use, bare surfaces and built-up area). Though the findings went contrary with the observation of Shahmohamadi (2015) and Chapman (2017) where they observed that urban land use/land cover depicts variation in the values of surface temperature. It is obvious that LST analysis has the capacity to bring out the spatial variation even though it may not be significant (Zhang *et al.,* 2013; Zhou & Wang, 2017).

It was observed that the relative humidity across the four-land cover/land uses has F-value of 0.080 and p-value of 0.971, showing that there is no discernible difference. Roshan *et al.* (2009) identified variation in the levels of relative humidity over different land uses/land cover components with equally temporal changes relative humidity. In this study, relative humidity over the entire land use/land cover though differences exist but not significant as observed in study a study by Huimin *et al.* (2021). The likely tendency for such result is due to small area coverage of the Kuje urban slum.

In contrast, the F-value for surface soil moisture is 2.173 and the p-value is 0.098, indicating that there is only a little variation in the amount of surface soil moisture among the four-land cover/land uses. The p-value is higher than the usual significance level of 0.05, hence it can be said that there is no statistically significant variation in the amount in surface soil moisture across the four various land cover/land uses. This is in line with the findings of Xiaolin *et al.* (2022) that observed that large-scale conversion of vegetated land to urban use leads to a significant variation in surface soil moisture over different land use/land covers. Similarly, Park and Kim (2017), Syed *et al.* (2013) and Babatola (2013) also had similar observations.

The ANOVA findings show that during the time span from 2002 to 2022, there are no statistically significant variations in the earth's surface temperature, relative humidity, and soil moisture across the four-land cover/land uses (See Table 7).

Conclusion

This study assessed slum growth impact on climatic elements in Kuje urban slum area of the Federal Capital Territory of Nigeria. There is serious decrease in agricultural land use area, bare surface and vegetal cover but with consistent increase in the, urban slum built up area. The vegetal land cover, agricultural land use, bare surface and built-up area from 2002 to 2022 had a steady but insignificant rise in earth surface temperature. The vegetal land cover, agricultural land use, bare surface and built-up area from 2002 to 2022 had a steady but insignificant decrease of relative humidity. The study also concluded that there is an insignificant increase in soil surface moisture from over the period of study. There is no significant variation in the value of earth surface temperature, relative humidity and surface soil moisture over the different land use/land cover in Kuje urban slum are from 2002 to 2022.

Based on the outcomes of this study, it was recommended that slum need to be incorporated into Kuje urban area planning through gentrification of buildings since demolition is not an option due to large concentration of indigenous people within the slum. Though there is no significant variation in climatic elements as a result of changing land use/land cover in the Kuje urban slum yet there is need for consistent monitoring of slum growth and climatic element anomalies over different land use/land cover.

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