SRYAHWA PUBLICATIONS

Annals of Ecology and Environmental Science
ISSN: 2637-5338 | Volume 7, Issue 1, 2025
https://doi.org/10.22259/2637-5338.0701001

RESEARCH ARTICLE

Trend Assessment of Land Surface Temperature Over Different Land Use/Land Cover in Greater Karu Urban Area of Nigeria

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Received: 27 January 2025 Accepted: 11 February 2025 Published: 14 February 2025

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Abstract

This study assessed trend of Land Surface Temperature over different land use/land cover in Greater Karu Urban Area of Nigeriausing multi-criteria research design. The remotely sensed imageries from Landsat TM, Landsat ETM and Landsat OLI that LANDSAT TM were obtained for 4 different epochs (1992, 2002, 2012 and 2022). The study used ESRI ArcGIS 10.8, ArcGIS Pro version 3.1.3 and Qgis version 3.22.5 for data acquisition, processing, modelling and analysis. Findings shows that during the dry season area with low LST (< 20^0C) and area with moderate LST (>20–23) declining trend with y = -46.29x + 196.25 and y = -44.18x + 340.7 respectively. Area with high LST (>23-26^0C) and area with extreme LST (>26^0C) had increasing trend with y = 21.75x + 192.7 and y = 68.72x - 6.75 respectively. During the wet season, area with low LST (< 20^0C) and area with moderate LST (>20–23) also depict declining trend with y = -7.83x + 35.8 and y = -9.91x + 59.9 respectively. Area with high LST (>23-26^0C) and area with extreme LST (>26^0C) had an increasing trend with y = 4.94x + 16.95 and y = 12.82x - 12.7 respectively. The findings shows that area having low LST (≤20^0C) and area with moderate LST (>20^0C-23^0C) have been decreasing within the study period of 1992 t0 2022 meaning a decadal decrease during the dry and wet season while area with high LST (>23^0C-26^0C) and area with extreme LST (>26^0C) had an increasing trend with equation depicting strong positive correlation between advancing years and increase in area with extreme LST values. The LST for newly developed LULC from 1992-2022 shows a positive increase for both dry season and wet season in GKUA but with the mean LST value higher in dry season and lower in wet season. The conversion of vegetal cover and cropland into bare surfaces and built-up area in quest for various urban infrastructures in GKUA for residency, transportation, industry, and other purposes causes major land use change that substantially affects LST, and this will surelyaffect the urban environment and ecosystem thereby decreases human thermal comfort for the urban dwellers.This study recommends urban greening of GKUA of Nasarawa State.

Keywords: Gkua, LST, Discomfort, Index, Trend, Change, Detection.

1. Introduction

In recent years, intensified urbanization and a growing urban population have amplified urban heat island effects, posing environmental security concerns (Chen *et al*., 2023). Concurrently, global climate change has increased the frequency of extreme heatwaves, worsening urban conditions and reducing thermal comfort (Ren *et al* 2022). Land Surface Temperature impact is notably pronounced in highly urbanized areas due to the high ratio of impermeable surfaces (Chen *et al*., 2023, Adeyeri*et al.,*2023). Higher LSTs are caused by impervious surfaces, poor urban layout, darker building colour and material, density of urban vegetation and heat-absorbing construction materials used to build urban infrastructures. Impervious surfaces absorb solar radiations creating higher temperatures (Wang 2015). In densely built areas, a poor layout can give rise to the 'canyon effect' where airflow is hindered and heat trapped, creating higher temperatures (Thani *et al* 2013). Dark building

Citation: Ishaya S, Babatunde Oladipo Lawal, Abbas G Idriss. Trend Assessment of Land Surface Temperature Over Different Land Use/Land Cover in Greater Karu Urban Area of Nigeria. Annals of Ecology and Environmental Science. 2025; 7(1): 1-12.

colours and non-reflecting building surfaces also produce higher temperatures (Ishaya, 2020). The conversion of natural surfaces into built form due to urban development and Land Use/Land Cover changes contribute to higher temperatures (Zhang and Liang, 2019) and the removal of vegetation reduces evapotranspiration, leading to less cooling effect through latent heat exchange and consequently higher LSTleading to human discomfort.

In Greater Karu Urban Area (GKUA), the expansion of built-up areas has the tendencies to contribute to the urban heat island effect. These urban areas typically have higher temperatures compared to surrounding rural areas due to increased heat retention by buildings, roads, and other infrastructure, as well as reduced vegetation cover. This can significantly impact human thermal comfort, especially during heatwaves (Houand Murayama, 2019). In line with these, it is of importance to ascertain the effect of different land cover changes on LST in Greater Karu Urban Area of Nasarawa State given its area size of 722 km^2 and a population of over two million being one of the fastest growing urban areas in the world, with a growth rate of 4.0 percent recorded annually (Rikko and Laka, 2013). The factors responsible for the choice of Greater Karu Urban Area is the urban structures and tendencies for changes in LSTdue to its proximity to Federal Capital Territory.

2. Land Surface Temperature Over Different Land Use Land Cover

Urban environmental research is replete with studies on the impact of land cover / land use on urban LST (Vogt and Oke, 2003; Rose and Devadas, 2009; Farina, 2012; Feng and Myint, 2015; Liu et al 2016). Liu et al. (2016) investigated the diurnal LST variation of Taipei City using MODIS and SPOT multispectral images. Their study shows that diurnal LST increased with increasing urbanization, with a positive linear increase observed at the early stages of urbanization. Farina (2012) assessed the relationship between vegetation types and LST in the city of Seville, Spain. Using NDVI as a proxy for vegetation cover, he reported a negative relationship between vegetation cover and LST. Even though the NDVI-LST relationship was generally found to be negative, it was observed that some vegetation cover types were more influential than others in determining the LST characteristics of an area. Similarly, Adewale F. Olatunde and Martins Momoh (2019) assessment of the relationship between urban growth and surface temperature in Abuja Municipal Area Council. It was revealed that the implication of urban growth on LST is an increase in mean LST of built-up areas to 27oC, 33oC and 36oC for 1986, 2001 and 2016 respectively with the highest value at city centre due to sparse vegetal cover. LST also increased across different LULC during the three epoch years. In the relationship between LST and urban growth, LST and NDBI revealed strong relationship with coefficient of determination (R^2) of 0.9610 for 1986; 0.9576 for 2001and 0.9732 for 2016.Korme (2020) carried out a study on the monitoring of land surface temperature in Bahir Dar city and its surroundings and their study reveals that vegetation cover had a mean LST of 32.22°C in 1987 and increased to 33.91°C in 2002. In their study, paved surface had a mean LST of 1.6°C higher than in 1987 and 36.62°C in 2002 because of urbanisation. While Me-ead and McNeil (2019) stated that climate change is the lead cause of LST increase in the Sahara and semi-arid parts of Southern Africa by 1.6°C in 2050s and the equatorial African countries by 1.4°C per year

3. Research Methodology

3.1 Study Area

Greater Karu Urban Area (GKUA) approximately located between latitudes 8º 5'N and 9º 25'E and longitudes 7º 54'E and 10º 42'N East of the Greenwich Meridian. It extends from the eastern boundary of

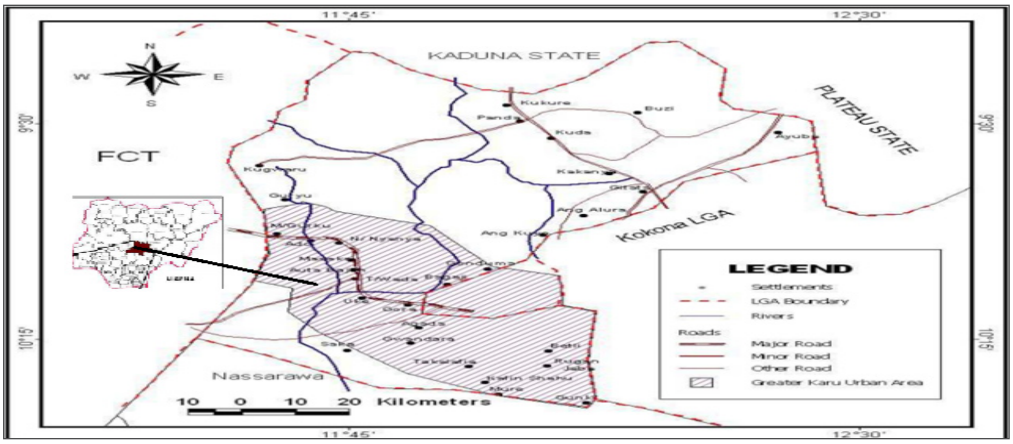

Figure 1. *Karu LGA showing the study area (GKUA) Source. Adapted from Rikko (2013)*

the Federal Capital Territory Abuja, (Old Nyanya) to Gora about 15 kilometers to Keffi. The planning area shares common boundaries with the Federal Capital Territory (FCT) Abuja to the west, Keffi Local Government Area (LGA) to the south, Nasarawa LGA and Jaba Local Government Area of Kaduna state to the north, (see details in figures 3.1 and 3.2). Greater Karu Urban Area has both urban and rural settlements. The major urban settlements comprising of Mararaba, New Karu, New Nyanya, Masaka and Uke as well as rural areas that have been overtaken by new urban development and engulfed by the larger ones such as Zhenwu, Luvu, Kuchikau, Kodepe, Aso Pada, Ado, Koroduma and One-Man Village. It has an area of 722 km^2 and a population of some 2 million (Rikko and Laka, 2013).

The average temperature of the study area is 29^0C. An annual average rainfall of 1250mm and an average wind speed of 9 km/h is experienced for the study area (Rikko and Laka, 2013). Tropical ferruginous soils make up the major soil units found in the study area. The parent material for the soils are from basement complex and sedimentary formations in the area. Laterite crust occurs extensively on the basement complex rocks while hydromorphic soils are common along river Benue trough and flood plains of major rivers (Audu *et al.,* 2018). The natural vegetation is of the park savannah type, featuring dense tropical woodland with shrubs and grasses (Udeh, 2010).Prior to the establishment of the FCT in 1975, the entire Karu area was a traditional agrarian community important for producing yams and grains to larger towns in Plateau and Niger states. It was dominated by small, sparsely populated settlements, with about 85% of the settlements having populations between 50-500 inhabitants (Audu *et al.,* 2018). Significant urban growth became a common landscape feature in the area only in the early 1990s following the construction of the new FCT and the subsequent transfer of the Federal Capital to Abuja in December 1991 (Audu *et al.,* 2018). These generated large influxes of people to the FCT and the neighboring settlements which were in themselves unplanned and with minimal resources, but which now accommodates over 60% of the Federal government and private sector workers in the FCT. such expansion may result to overcrowding, therefore necessary to investigate the Land Surface Temperature over different Land Use/Land Cover in Greater Karu Urban Area of Nigeria.

3.2 Research Design, Data and Software's Used

Multi-criteria research design was used to acquire,process and analyse remotely sensed satellite imageries and other related dataset. The remote data used were Landsat TM, Landsat ETM and Landsat OLI that containLand Surface Temperature data emitted by objects in the study area and stored the information as a digital number. These images were obtained for 4 different epochs; 1992, 2002, 2012 and 2022. The study used ESRI ArcGIS 10.8, ArcGIS Pro version 3.1.3 and Qgis version 3.22.5 for data acquisition, processing, modelling and analysis.

Table 1. *Images used in the study*

S/No.	Study Area	Path/Row	Satellite Date of Acquisition	Satellite Sensor I.D	Bands	Resolution (m)
	GKUA	188/54	1992	Landsat 4 Thematic Mapper (TM)	2-5,7	30
					6	60
			2002 and 2012	Landsat 7 Enhanced Thematic Mapper Plus (ETM+)	2-5,7	30
					6	60
			2022	Landsat 8 OLI/TIRS	2 -7	30
					10	30
			2022	ASTER (GDEM)	-	1-arc seconds

Source: *Researcher Compilation, 2024.*

3.3 Data Analysis

3.3.1 Image Pre-processing

QGIS 3.22.5 software was used for gap filling. Atmospheric correction was performed to remove the effects of solar illumination differences and other atmospheric anomalies (like atmospheric path reflectance, electromagnetic scattering/absorption) from the imageries. Using Available Band List Module in Qgis, false colour Bands were combined to form an Image. The Bands were 432 in which vegetation appears red in colour, water appears cyan and bare surface appears white.The study area was subsets by masking out all areas not falling within the study area. This was done by overlaying a vector shape file on the raster image and assigning values of 1 to the area of interest and 0 to the rest of the image respectively (Imran *et al.,* 2022).

3.3.2 Classification Accuracy

Kappa statistic was used in classification accuracy. Kappa values are characterized as <0 as indicative of no agreements and 0–0.2 as slight, 0.2–0.41 as fair, 0.41–0.60 as moderate, 0.60–0.80 as substantial and 0.81–1.0 as almost perfect agreement (Imran *et al.,* 2022). Accuracy assessment tasks was performed on the 1992, 2002, 2012 and 2022 imageries. The classification accuracy calculates the statistics of percentages of accuracy relative to error matrix results. The error matrix compares the historical values to the assigned class values. Kappa statistics measures the ability to provide information about a single matrix as well as to compare matrices (Himanshu and Subhanil, 2021).

3.4 Estimation of Land Surface Temperature

To estimate the LST from the pre-processed Landsat images, the temperature data stored as DN values in the thermal band 10 (low gain band) for ETM+ and band 6 for TM was converted to spectral radiance values using the following standard LMin and LMax spectral radiance scaling factors equation (NASA, 2011):

Radiance = LMaxλ – Lminλ * QCAL – QCALMIN + Lminλ

QCALMax– QCALMin ……………………….eq.1

Where: QCAL = digital number

LMINλ = spectral radiance scales to QCALMIN

LMAXλ = spectral radiance scales to QCALMAX

QCALMIN = minimum quantized calibrated pixel value (usually = 1)

QCALMAX = maximum quantized calibrated pixel value (usually = 255)

The scene calibration data were available on the metadata file of each Landsat scene. Having computed the spectral radiance values for each of the Landsat scenes, were subsequently converted to temperature values (Kelvin) using the inverse of the Planck function shown below:

T = K2/ln[K1*E/Radiance+1]…………………………………………………………… eq. 2

Where: T = Effective at-satellite temperature in Kelvin

K2= Calibration constant 2

K1= Calibration constant 1

ε = Emissivity (typically 0.95)

Radiance = Spectral radiance

3.5 Land Surface Temperature (LST) Trend Analysis

Linear regression was used to determine the linear trends of the rainfall, temperature, relative humidity and cholera cases. The linear regression formula is given thus:

y = a + bx……………………………………….eq. 3

Where ***a*** is the intercept of the regression is line on the y-axis;

b is the slope of the regression line.

In equation 3, the values of ***a*** and ***b*** were obtained using equations 4 and 5.

$$a = \frac{\sum y - b(\sum x)}{n} \quad \text{……………………………… eq. 4}$$

$$b = \frac{n(\sum xy) - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)^2} \quad \text{……………………… eq. 5}$$

In determining LST trends and measurement of variability, standard deviation which provides the deviation from normal for the LST, was determined and plotted using 2017 Microsoft Excel Statistical Tool. Using the produced graphs, abnormal situations were ascertained.

Or

Linear Trend Model is;

$Y=\beta_0+\beta_1X+\epsilon$……………………………………………………………………………………… eq. 6

Where;

β_0 = The average value

β_1 = The value expected to increase for each additional value.

ϵ = other factors affecting value obtained.

The R^2 expressed how well the linear equation fits into the data. The trend model R^2 was statistical measured to represents the proportion of the variance in the dependent variable that is predictable from the independent variable(s).

4. Result and Discussion

4.1 Land Use/Land Cover Characterization and Changes from 1992 to 2022

Table 4.2 and Figure 4.2 depict LU/LC changes between 1992 to 2022 in GKUA. Between 1992 to 2002, water bodies area coverage increased by 0.2km2 (0.03%), from 2002 to 2012 it had an increased value of 1.3km2 (0.18%) and from 2012 to 2022 had decreased value of 0.40 (0.06%). Considering the pattern of changes in cropland area coverage, between 1992 to 2002 there was an increase of 56.9 km2 (7.87%), but a decrease of -98.9km2 (-13.68%) from 2002-2012, from 2012-2022 an increase of 3.10km2 (0.43%) was observed. The distribution of vegetal coverage in GKUA shows a decrease of -65.6km2 (-9.07%) but depicts an increase of 18.4km2 (2.55%) between 2002 and 2012 and a pronounced decrease of -145.70km2 (-20.15%) between 2012-2022. Over the study period, built-up areas have been in a consistent increase from 1992 to 2022. Between 1992 to 2002, built up increased by 13.0 km2 (1.8%), between 2002 to 2012 a tremendous increase of 43.1 km2 (5.96%), from 2012 to 2022 built-up area grew with 144.3km2 (20%). The bare surface decreased by 4.5 km2 (0.62%) from 1992 to 2002, while from 2002 to 2012 it increased by 36.1 km2 (4.99%), and between 2012 to 2024, the bare surface increased by 54.8 km2 (7.58%).

Table 1. *Change Detection of LU/LC from 1992 to 2022 in GKUA*

Classes	1992 – 2002		2002 – 2012		2012 - 2022		1992 – 2022	
	Changes (Km^2)	%	Changes (Km^2)	%	Changes (Km^2)	%	Changes (Km^2)	%
Water bodies	0.2	0.03	1.3	0.18	-0.40	-0.06	1.1	0.2
Cropland	56.9	7.87	-98.9	-13.68	3.10	0.43	-38.9	-5.4
Vegetal cover	-65.6	-9.07	18.4	2.55	-145.70	-20.15	-192.9	-26.7
Built-up	13.0	1.80	43.1	5.96	88.20	12.20	144.3	20.0
Bare surface	-4.5	-0.62	36.1	4.99	54.80	7.58	86.4	12.0

Source: Researcher Analysis, 2024.

From 1992 to 2022, water bodies increased by 1.1 km2 (0.2%), cropland decreased by 38.9 km2 (5.4%), vegetal cover decreased by 192.9 (-26.7%), the built-up area increased by 144.3 Km2 (20%), the bare surface also increased by 86.4Km2 (12.2%) (Table 4.2 and figure 4.2). Cropland and vegetal cover experienced more of the decrease while the built-up and bare surface experienced more of the increase with respect to change in the GKUA throughout the study. This is due to consistent housing demands by workers and economic prospect seekers in the Federal Capital City (FCC) of the Federal Capital Territory of Nigeria who can't afford accommodation with the FCC. The demolition of slums within the FCC forces low-income earners to move into Greater Karu Urban Areas and commute to work in the FCC during the working days of the week. The findings in GKUA aligned with the observations of Kumar & Sangwan (2013) that land use changes are more of an increase in the built-up area and bare surface but with a decrease in the vegetal and agricultural land. Ade and Afolabi (2013) findings of change detection in the Federal Capital Territory of Nigeria from 1987-2007; Balogun, Adeyewa, Balogun, and Morakinyo (2011) observed urban expansion and land use changes in Akure. Ishaya 2009, Ejaro& Abdullahi (2013) and Du, Jin, Yang, Yang, & Zhou (2014) observed also an increase in the built-up area and bare surface with a decrease in vegetal cover and agricultural land. In GKUA, the ever-increasing population, migration, and changing functions of urban areas as caused by urbanization lead to land use changes, which in turn affects land use/land cover.

4.2 Land Surface Temperature(LST) of GKUA from 1992 to 2022

Urban areas typically have a higher density of heat absorbing materials such as asphalts, concretes and bricks. These materials absorb and retain heat more effectively than natural surfaces like vegetation or soil, leading to elevated temperatures. Structural growth in urban areas in recent years exacerbate the tendencies for increasing LST in many urban centres. The dry and wet season land surface temperatures for the years 1992, 2002, 2012 and 2022 of Greater Karu Urban Area is presented in this section. Each year has its thermal signatures as obtained from the analysis the LST from the identified LULC.

4.2.1 Dry Season LST of Greater Karu Urban Area from 1992 to 2022

Table 2 and Figure 2 presents the Land Surface Temperature (LST) values during the dry season (November to March) for different LU/LC classes in the GKUA from 1992 to 2022.In the year 1992,dry seasonLST varies over space with area having low LST ≤20⁰C) covering 3.9% of the total area, area with moderate LST (>20⁰C-23⁰C) covered 18.3% of the total area, area with high LST (>23⁰C-26⁰C) covered 48.0% of the total area while area with extreme LST (>26⁰C) covering 29.8% of the GKUA.In the year 2002 dry season, low LST ≤20⁰C) area occupied 3.9% of the total area, area with moderate LST (>20⁰C-23⁰C) covered 18.3% of the total area, area with high LST (>23⁰C-26⁰C) covered 48.0% of the total area while area with extreme LST (>26⁰C) covering 29.8% of the GKUA. LST result in the dry season of 2012, shows that area that had low LST $\leq 20^0C$) covered 6.2% of the total area, area with moderate LST ($>20^0C-23^0C$) dominate 30.7% of the study area, area with high LST ($>23^0C-26^0C$) covered 44.1% of the area while area with extreme LST ($>26^0C$) covering 19.0% of the study area. During the dry season in the year 2022, low LST $\leq 20^0C$) area occupied 6.2% of GKUA, area with moderate LST ($>20^0C-23^0C$) covered 26.9% of GKUA, area with high LST ($>23^0C-26^0C$) covered 28.0% of the total area while area with extreme LST ($>26^0C$) covering 38.9% of the GKUA (See Table 2).

Table 2. *DrySeason LST of GKUA from 1992 to 2022*

Dry Season LST of GKUA in 1992			Dry Season LST of GKUA in 2002		
Classes	Area (Km^2)	Percentage	Classes	Area (Km^2)	Percentage
< 20	204.5	28.3	< 20	28.1	3.9
> 20 - 23	371.8	51.4	> 20 - 23	132.4	18.3
> 23 - 26	120.2	16.6	> 23 - 26	347.2	48
> 26	26.4	3.7	>26	215.2	29.8
Total	722.9	100	Total	722.9	100
Dry Season LST of GKUA in 2012			**Dry Season LST of GKUA in 2022**		
Classes	Area (Km^2)	Percentage	Classes	Area (Km^2)	Percentage
< 20	44.9	6.2	< 20	44.6	6.2
> 20 - 23	222.2	30.7	> 20 - 23	194.6	26.9
> 23 - 26	318.7	44.1	> 23 - 26	202.2	28
> 26	137.1	19	> 26	281.5	38.9
Total	722.9	100	Total	722.9	100

Source. *Researcher Analysis 2024*

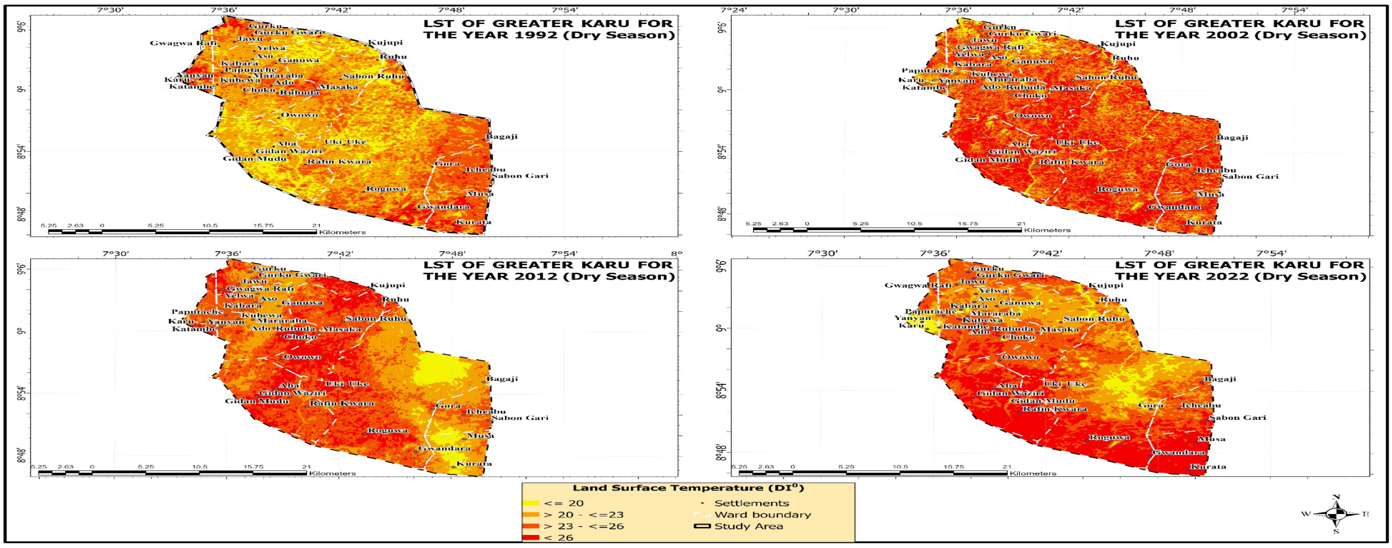

Figure 2. *Dry Season LST of GKUA from 1992 to 2022*

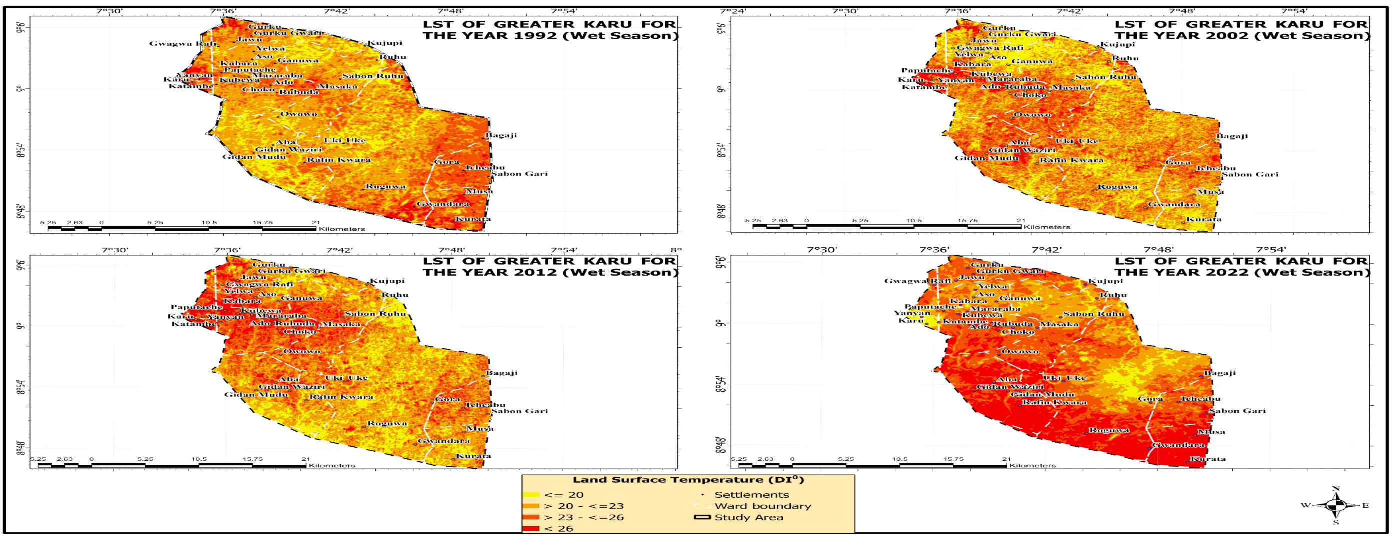

Figure 3. *Wet Season LST of GKUA from 1992 to 2022*

Table 3. *Wet Season LST of GKUA from 1992 to 2022*

Wet Season LST of GKUA in 1992			Wet Season LST of GKUA in 2002		
Classes	**Area (Km^2)**	**Percentage**	**Classes**	**Area (Km^2)**	**Percentage**
< 20	204.4	28.3	< 20	153	21.2
> 20 - 23	371.8	51.4	> 20 - 23	317.4	43.9
> 23 - 26	120.2	16.6	> 23 - 26	207.6	28.7
> 26	26.5	3.7	> 26	44.9	6.2
Total	722.9	100	Total	722.9	100
Wet Season LST of GKUA in 2012			**Wet Season LST of GKUA in 2022**		
Classes	**Area (Km^2)**	**Percentage**	**Classes**	**Area (Km^2)**	**Percentage**
< 20	66.4	9.2	< 20	44.6	6.2
> 20 - 23	132.4	18.3	> 20 - 23	194.5	26.9
> 23 - 26	317.7	43.9	> 23 - 26	202.2	28
> 26	206.4	28.5	> 26	281.6	39
Total	722.9	100	Total	722.9	100

4.2.2 Wet Season LST of Greater Karu Urban Area from 1992 to 2022

Table 3 and Figure 3 presents the Land Surface Temperature (LST) values during the wet season for different LU/LC classes in the GKUA from 1992 to 2022. In the year 1992, wet season LST varies over space with area having low LST ≤20^0C) covering 28.3% of the total area, area with moderate LST (>20^0C-23^0C) covered 51.4% of the total area, area with high LST (>23^0C-26^0C) covered 16.6% of the total area while area with extreme LST (>26^0C) covering 3.7% of the GKUA. In the year 2002 wet season, low LST ≤20^0C) area occupied 21.2% of the total area, area with moderate LST (>20^0C-23^0C) covered 43.9% of the total area, area with high LST (>23^0C-26^0C) covered 28.7% of the total area while area with extreme LST (>26^0C) covering 6.2% of the GKUA. LST result in the wet season of 2012, shows that area that had low LST ≤20^0C) covered 6.2% of the total area, area with moderate LST (>20^0C-23^0C) dominate 30.7% of the study area, area with high LST (>23^0C-26^0C) covered 44.1% of the area while area with extreme LST (>26^0C) covering 19.0% of the study area. During the wet season in the year 2022, low LST ≤20^0C) area occupied 9.2% of GKUA, area with moderate LST (>20^0C-23^0C) covered 18.3% of GKUA, area with high LST (>23^0C-26^0C) covered 43.9% of the total area while area with extreme LST (>26^0C) covering 28.5% of the GKUA (See Table 2).

4.2.3 LST Trends from 1992 to 2022

The trend in land surface temperature (LST) is a crucial indicator of change in temperature and has been observed to increase over the past several decades. Dry and wet season LST Trends from 1992 to 2022 for GKUA are presented below.

4.2.4 Dry Season LST Trends from 1992 to 2022

Findings in Figure 4a shows that area with low LST (< 20^0C) during the dry season had a declining trend with equation of y=-46.29x+196.25 meaning a decadal decrease in area with low LST with R^2= 0.5181 (51.81%) which shows significantnegativecorrelation between advancing years and area with low LST. It was observed that area with moderate LST (>20–23) during the dry season had a declining trend with equation of y=-44.18x+340.7 meaning a decadal decrease in area having moderate LSTwith R^2=0.3154 (31.54%) which shows substantial negative correlation between advancing years and area with moderate LST (Figure 4b). Area with high LST (>23-26^0C) during the dry season had an increasing trend with equation of y=21.75x+192.7 depicting a decadal increase in area havinghigh LSTwith R^2 = 0.0711(7.11%) which shows positive correlation between advancing years and increase in area with high LST values (Figure 4c). It was observed that area with extreme LST (>26^0C) during the dry season had an increasing trend with equation of y=68.72x-6.75 portraying a decadal increase in area having extreme LSTwith R^2=0.6544(65.44%) which depict positive correlation between advancing years and increase in area with extreme LST values (Figure 4d).

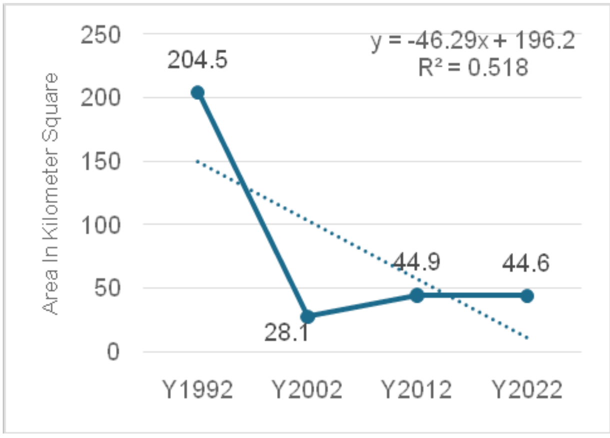

Figure 4(a). *Dry Season LST< 20 Trend*

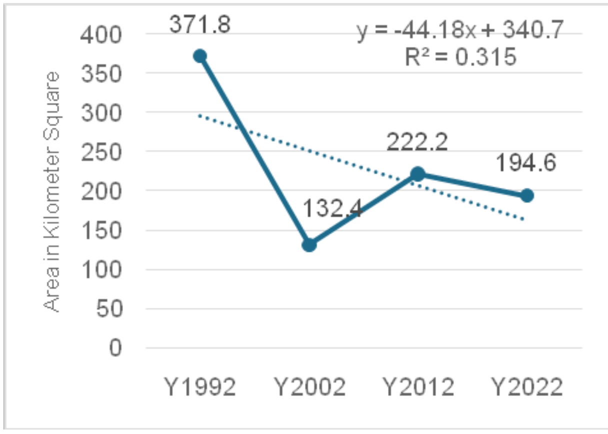

Figure 4(b). *Dry Season LST > 20 - 23Trend*

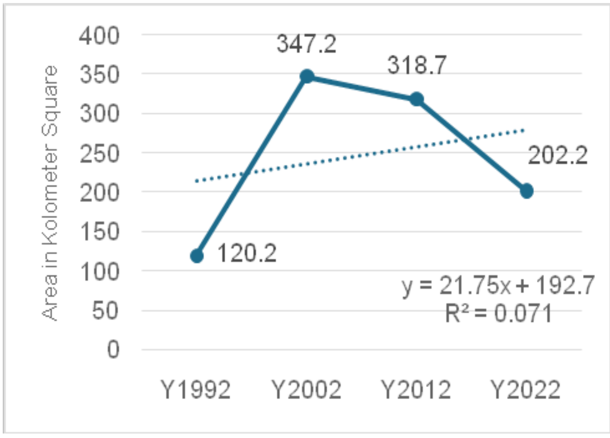

Figure 4(c). *Dry Season LST> 23 - 26Trend*

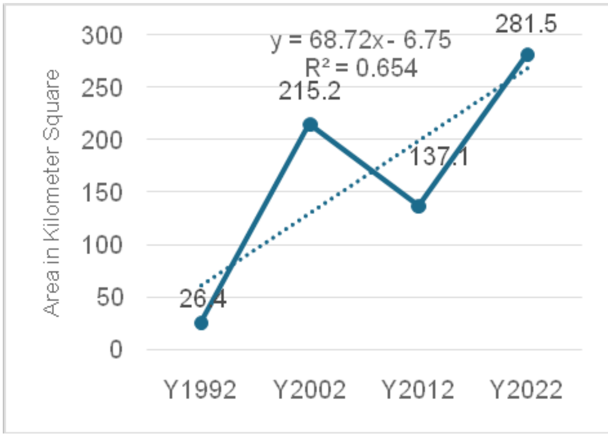

Figure 4(d): *Dry Season LST> 26 Trend*

4.2.5 Wet Season LST Trends from 1992 to 2022

Result shows that area with low LST (< 20^{0}C) during the wet season had a declining trend with equation of y=-7.83x+35.8 meaning a decadal decrease in area with low LST with R^2 = 0.9567 (95.67%) depictingstrongnegative correlation between advancing years and area with low LST (Figure 5a). It was observed that area with moderate LST (>20–23) during the wet season had a declining trend with equation of y=-9.91x+59.9 meaning a decadal decrease in area having moderate LSTwith R^2=0.709 (70.9%) which shows substantial negative correlation between advancing years and area with moderate LST (Figure 5b). Area with high LST (>23-26^{0}C) during the wet season had an increasing trend with equationy=4.94x+16.95 depicting a decadal increase in area having high LSTwith R^2 = 0.3241 (32.41%) which shows positive correlation between advancing years and increase in area with high LST values (Figure 5c). It was observed that area with extreme LST (>26^{0}C) during the wet season had an increasing trend with equation of y=12.82x-12.7 portraying a decadal increase in area having extreme LSTwith R^2 = 0.9257 (92.57%) which depict strong positive correlation between advancing years and increase in area with extreme LST values (Figure 5d).

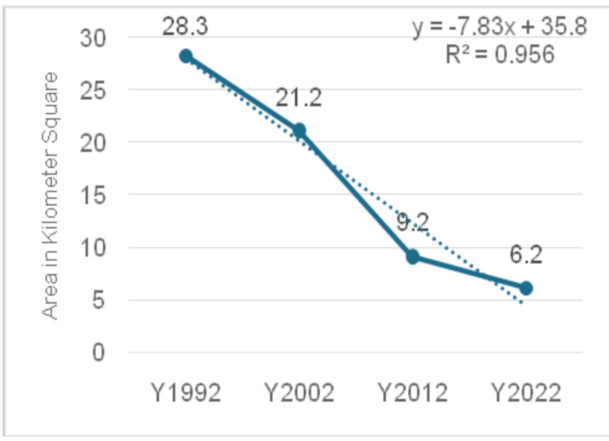

Figure 5(a). *Wet Season LST < 20 Trend*

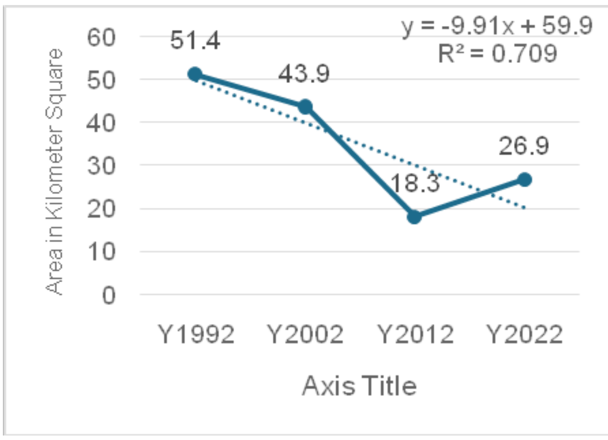

Figure 5(b). *Wet Season LST > 20 - 23 Trend*

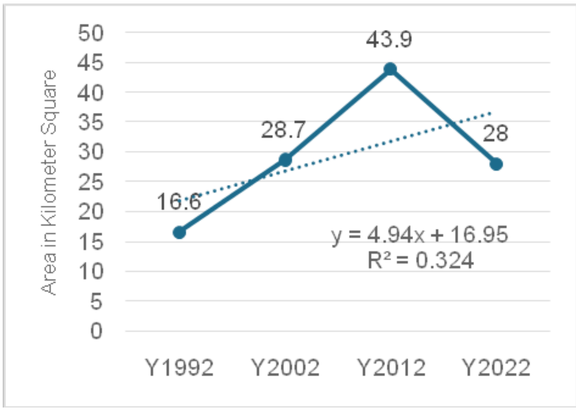

Figure (5)c. *Wet Season LST > 23 - 26 Trend*

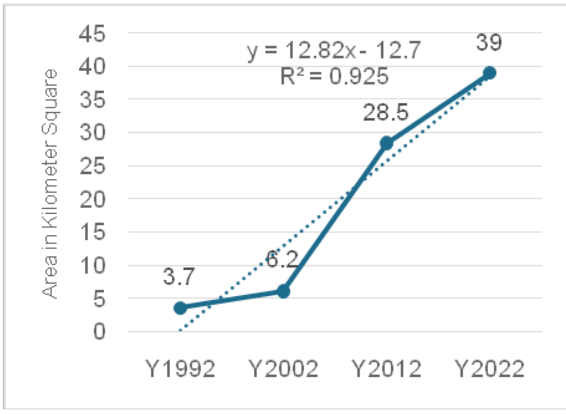

Figure 5(d). *Wet Season LST> 26 Trend*

Generally, for both dry and wet season, GKUA reveals significant warming trends which coincides with increase in built up area and bare surfaces. Hou*et al* (2019) and Mumtaz,*et al.* (2020) observed that globally, land surface temperatures have been rising as data from various sources, including satellite measurements and ground-based observations, show a clear upward trend in average temperatures. The loss of vegetal cover and agricultural cropland explains impact of urbanization on the earth surface hence increasing LST and temperature variability, indicating environmental stress. LU/LC changes are related to urbanization, involving replacement of the natural environment (pervious surfaces) with the warm concrete based urban structures(20% of built-up and 12.2% of bare surface) thereby exacerbating temperature rise. These structures are characterized with high heat absorbing capacities, thus leading to continual rise in land surface temperature in rapid growing town (Abaje*et al.,* 2016., Ishaya, 2020 & Olubukola *et al.,* 2023). Also, Imran et al. (2021), reckons that a change in LST is related not only to land use/land cover type conversion, but also in the existence and increase of greenhouse effect due to other anthropogenic activities in urban areas.

4.2.6 LST in newly developed LULC in GKUA from 1992 - 2022

Resultsuggests a warming trend in LST during the dry and wet season in the GKUA. The LST obtained for newly developed LULC from 1992-2022 shows a positive increase for both dry season and wet season in GKUA. Despite the changes in both the dry and wet seasons GKUA, the LST obtained during the dry season is notably higher than the obtained LST during the wet season for all the LULC (See Table 3). During the dry season, the mean LST in the newly developed LULC of GKUA from 1992-2022 depicts a mean of value of 26.57^{0}C in 1992 and 31.435^{0}C in 2022 and mean LST change of 4.44^{0}C from 1992-2022. The change is significant compared to wet season because the area has no tree cover anymore while "vegetal cover" represents trees, agricultural lands, deciduous forest, mixed forest and croplands,coniferous forest, parks, scrub, and other types of vegetation. Therefore, during wet season, there is reduction in temperature compared to dry season due to cultivation. The mean value of LST during the dry and wet seasons in the newly developed LULC of the GKUA from 1992-2022 shows a meanvalue of 27.27^{0}C minimum and 27.30^{0}C maximum with mean LST change of 2.5^{0}C from 1992-2022. This means cooler temperatures in all the LULC during the wet season than dry season in GKUA (See Table 4). This is as a result of more cloud cover, more rainsduring the wet season that cools the air as it evaporates, wet surfaces and regeneration of vegetal cover that absorbed, scatter and reflects solar energy back into space thereby reducing the amount of solar radiation that reaches the surface. The observation in this study concurs with the findings of Imran et al. (2022), thatconversion of vegetal cover and cropland into bare surfaces and built-up area in quest for various urban infrastructures in urban area for residency, transportation, industry, and other purposes causes major land use change that substantially affects Land Surface Temperature (LST) by unbalancing the surface energy budget. Higher LST in urban areas affects the urban environment and ecosystemthereby decreases human thermal comfort for the urban dwellers. The findings of this study can be compared to the work of Tan *et al*. (2020), who discovered a 3.5°C increase in the winter temperature of the Dongting Lake, China, due to the expansion of built-up and dryland area during 1995 to 2013; Kafy*et al (*2020) also observed a 3°C rise in LST resulting from LU/LC changes caused by urbanization from 1997-2017; Traore *et al.* (2021) documented a 1°C rise in the LST of Bangui City, Central Africa, because of a 130% expansion in built-up areas between 1986 and 2017. These findings coincide with the observed changes in LST associated with alterations in land surface conditions due to land cover changes over the study years in GKUA.

Table 4. *LST in newly developed LULC in GKUA from 1992 - 2022*

Land cover change	Dry Season Mean LST			Wet Season Mean LST		
	1992	2022	Change	1992	2022	Change
Built-up Area-Built-up Area	24.5	26.5	2.0	23.7	26.2	2.5
Built-up Area-Built-up Area	28.9	32.2	3.3	27.5	28.2	0.7
Built-up Area-Built-up Area	28.0	32.2	4.1	26.4	27.7	1.3
Built-up Area-Built-up Area	27.6	31.1	3.5	26.9	27.7	0.8
Built-up Area-Built-up Area	25.0	32.5	7.5	27.6	29.8	2.2
Water bodies-Vegetation	27.6	28.3	0.8	24.8	25.5	0.7
Water bodies-Vegetation	27.3	32.1	4.9	25.3	27.4	2.1
Water bodies-Built-up Area	25.3	30.9	5.6	27.6	29.7	2.1
Water bodies-Bare soil	26.4	31.8	5.3	26.8	29.7	2.9
Water bodies-Water bodies	26.8	28.9	2.2	23.5	25.8	2.3
Vegetation-Lowland	27.0	31.7	4.7	25.8	27.3	1.5
Vegetation-Built-up Area	26.5	32.0	5.5	25.7	27.9	2.2
Vegetation-Built-up Area	25.3	31.9	6.6	24.3	29.4	5.1
Vegetation-Bare soil	26.6	31.8	5.2	24.6	27.8	3.2
Bare soil-Bare soil	26.7	29.2	2.5	24.1	26.4	2.3
Bare soil-Bare soil	26.5	30.1	3.6	25.3	27.1	1.8
Bare soil-Built-up Area	26.7	32.0	5.2	25.4	28.2	2.8
Bare soil-Built-up Area	26.6	31.8	5.2	25.9	29.7	3.8
Bare soil-Bare soil	26.2	31.7	5.5	24.6	28.2	3.6
Copland-Water bodies	25.7	28.8	3.2	23.3	25.9	2.6
Cropland-Vegetation	27.1	32.4	5.3	25.2	28.6	3.4
Cropland-Built-up Area	27.2	32.0	4.8	26.5	29.7	3.2
Cropland-Bare soil	27.2	32.3	5.1	25.6	29.0	3.4
Mean	**26.57**	**31.435**	**4.44**	**27.27**	**27.30**	**2.45**

Source: Researcher Analysis, 2024.

It is obvious that Greater Karu Urban Area is experiencing discomfort due to rapid urbanization. This finding agrees with Anwar *et al* (2022), their investigation shows that intense urbanization alters the microclimate and ecology of cities by converting naturally vegetated and permeable surfaces into impervious built-up surfaces. These artificial impermeable surfaces re-balance the surface energy budget by storing solar heat due to their higher thermal conductivity, and consequently, increase the LST. The higher the LST in urban area the higher the Human Thermal Comfort (HTC) in GKUA.

5. Conclusion

This study examines the trend of land surface temperature over different land use/land cover in Greater Karu Urban Area of Nsarawa State in Nigeria. This study concludes that area having low LST (≤20^0C) and area with moderate LST (>20^0C-23^0C) have been decreasing within the study period of 1992 t0 2022 meaning a decadal decrease during the dry and wet season while area with high LST (>23^0C-26^0C) and area with extreme LST (>26^0C) had an increasing trend with equation depicting strong positive correlation between advancing years and increase in area with extreme LST values. The LST for newly developed LULC from 1992-2022 shows a positive increase for both dry season and wet season in GKUA but with the mean LST value higher in dry season and lower in wet season. The conversion of vegetal cover and cropland into bare surfaces and built-up area in quest for various urban infrastructures in GKUA for residency, transportation, industry, and other purposes causes major land use change that substantially affects LST. It is safe to conclude that increase in LST in GKUA surely will affectthe urban environment and ecosystem thereby decreases human thermal comfort for the urban dwellers.

5.1 Recommendations

Based on the findings of this study the following recommendations were made;

i. Increase green spaces by creating and expand urban parks, green belts, and recreational areas.

ii. Encourage the development of community gardens to increase green coverage.

iii. Integrate sustainable urban planning practices to reduce impervious surfaces and promote cooling. This includes using permeable materials for pavements and roads.

iv. Implement zoning regulations that promote mixed land uses and the incorporation of green spaces.

v. Plant trees along streets and roads to provide shade and lower surface temperatures.

vi. Encourage the installation of green roofs and vertical gardens to reduce heat absorption in buildings.

vii. Use cool or reflective roofing materials to minimize heat absorption in buildings.

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