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Modelling the Effect of Land Use and Land Cover Variations on the Surface Temperature Values of Nairobi City, Kenya

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Abstract Urbanization replaces natural vegetation with impervious surfaces such as roads and buildings. Since impervious surfaces have higher thermal energy absorption and retention capacities, they store thermal energy during the day and slowly released it at night. The energy exchange in conjunction with anthropogenic heat contributes to the development of urban heat islands. To establish the relationship existing between urban surface temperature values, land uses and land covers, information on the same provided by Landsat TM imageries of the years 1988 and 1995 as well as Landsat ETM+ imageries of the years 2000, 2005, 2010 and 2015 consisting of Band 2 (Green: 0.52µm –0.60 µm), Band 3 (Red: 0.63µm - 0.69µm), Band 4 (the NIR: 0.76µm – 0.90µm) and Band 6 (10.4 – 12.5µm) were used. The objectives of this study were to establish the distribution of land uses and land covers within the city between the years 1988 to 2015, to establish the spatial variations in surface temperature values in the city between the years 1988 to 2015 and to determine the relationship existing between the land uses and land covers of the city and the surface temperature values. To accomplish the objectives, spatio-temporal models of land uses and land covers as well as surface temperature variations within the city were evolved to aid in the postulation of a quantitative model explaining how land uses and land covers determine the surface temperature distribution in the city. This was undertaken in furtherance to theoretical postulations on the effect of urbanisation indicators notably the land use and land cover alterations on global warming and climate change.

Keywords Surface Temperature, Urban Heat Islands, Land Use, Land Cover, Geospatial Systems

1. Introduction

Higher urbanization rates present a major challenge to urban sustainability especially to the developing countries which are characterised by low technical and financial capacities for urban environmental management. In the recent decades, realisation that global warming and climate change is accentuated by increased urbanisation and greenhouse gas emissions has heightened studies on the links between urbanisation indicators such as development densities, land uses, land covers and the urban environmental quality parameters such as the urban heat islands, air quality, climate change and global warming. Some of these studies posit that a proportion of the 0.5°C global warming seen over the last century is attributed to increased urbanization (Kukla *et al*., 1986; Changnon, 1992; Wood, 1988; Jones *et al.*, 1990; Wigley and Jones, 1988; Nasrallah and Balling, 1993). The urban land uses and land covers notably the buildings and the green belts attenuate wind flow within the urban canopy layer which in turn affects the distribution of the urban thermal values. The above explains the occurrence of higher surface temperature values in the cities relative to their hinterlands. Scholars therefore agree that there is a significant relationship existing between urban land uses, land covers and the surface temperature values. The fundamental question is therefore to what extent are land use and land cover parameters of urban built-up, open and transitional areas as well as vegetation cover determines the spatial distribution of the surface temperature values within the city (Chan *et al.,* 2003; Givoni, 1998; Soulhac *et al.,* 2001; Britter and Hanna, 2003; Golany, 1996; Karatasou *et al.,* 2006).

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2. The Aim and Objectives of the Study

The aim of this study was to establish the relationship existing between the land use, land cover and the surface temperature values of Nairobi city as derived from geospatial measurements. This was undertaken in furtherance to the postulations on the effects of urbanisation on global warming and climate change. Accordingly, the objectives of the study were: -

i. To establish the distribution of land uses and land covers within the city between the years 1988 to 2015,
ii. To establish the spatial variations in surface temperature values in the city between the years 1988 to 2015,
iii. To determine the relationship existing between the land uses and land covers of the city and the surface temperature values.

3. Methods and Materials

This study adopted both descriptive and quantitative research designs. While descriptive designs are concerned with explaining who, what, when and how a phenomenon occurs over space, quantitative designs explains how various factors affecting an occurrence of a phenomenon are related (Babbie, 2002; Cooper *et al.,* 2003). In this study, the entire land surface constituting the jurisdictions of the Nairobi City County Government which is bounded within the longitudes 36° 40’ and 37° 10’E and between latitudes 1°09’ and 1° 28’S covering an area of 716 km^2 constituted the target population. Sampling was inappropriate for the imageries used in the study had full spatial coverage of the city.

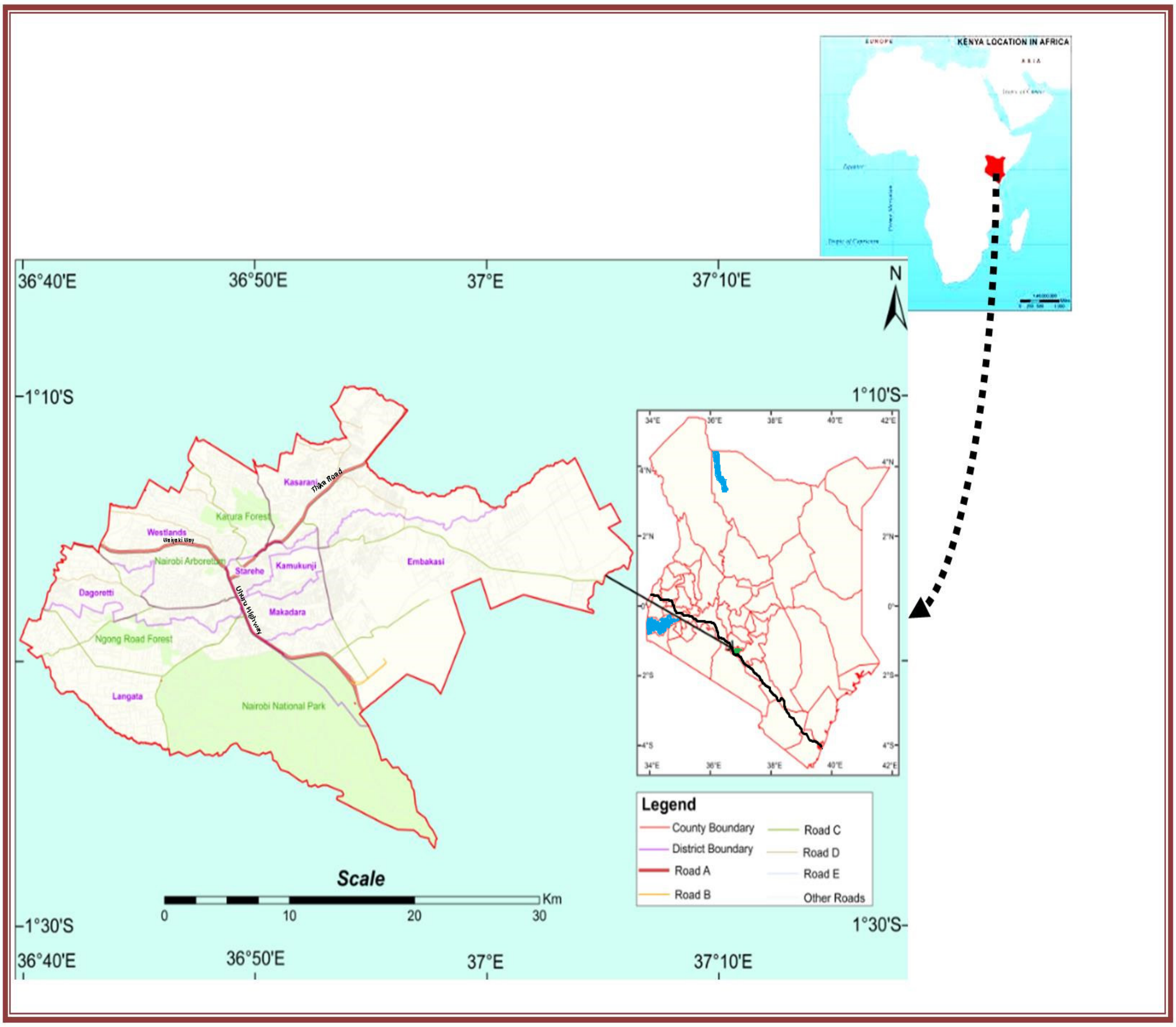

Figure 1. The Study Area

To evaluate the nature, magnitude, pattern and trends of land use and land cover for the years between 1988 and 2015, this study utilised cloud-free satellite imageries of the city as follows:- Landsat TM imageries - Band 2 (Green: 0.52μm –0.60 μm), Band 3 (Red: 0.63μm - 0.69μm) and Band 4 (the NIR: 0.76μm – 0.90μm) for the years 1988 and 1995 while Landsat ETM+ imageries at the same bands were used for the years 2000, 2005, 2010 and 2015. In both the cases, Band combinations of Red, Green and Near Infra-Red were used due to the combination's appropriateness in facilitating discrimination of urban built-up areas, water bodies and vegetation categories. The swath for the Landsat TM and Landsat ETM+ is 185 km while the spatial resolutions of the bands under consideration are 30m. Therefore, both the spatial and spectral resolutions of the procured imageries matched. While the imageries used in this study were procured from the archives of the European Space Agency through the Nairobi based Regional Centre for Mapping of Resources for Development (RCMRD), secondary information notably the 1: 50,000 scale topographical maps of the city were obtained from the Survey of Kenya.

Unsupervised digital image processing technique which relies on expertise knowledge on spectral and radiometric characteristics of land uses and land covers was used in land use and land cover classification. The procedure involved image pre-processing, design of classification schema, image classification and accuracy assessment. The pre-processing procedures are undertaken to correct for geometric and radiometric errors and to calibrate the imageries to reflectance percentages of various surface objects. The imageries were geo-referenced using 11 Ground Control Points whose coordinates were obtained from the 1:50,000 scale topographical maps of the study area. Further procedures involved the extraction of the study area from the imageries using ARCGIS 10.3 Software, for the procured imageries covered the city (the study area) and its environs. The extracted imageries were then exported to ILWIS 3.6 Academic environment in TIFF Format.

Upon launching the extracted temporal imageries of the city in the ILWIS 3.6 Academic environment, colour separation operations were undertaken. This was followed by rebuilding of the colour composites using true-colour band combination (Bands 4-3-2) to facilitate visualisation and identification of the imagery features. Other operations undertaken to enable the assignment of the classification schema to the pixels after rebuilding the colour composites of the extracted imageries were creation of map list, sample set and classification domain. Upon assigning at least 2500 number of pixels per land use and land cover category, the classified imageries were assessed for accuracy through crossing the same with sample sets. The accuracies of the classified imageries were further validated through ground-truthings of which coordinates of selected pixels were identified using Global Positioning System (GPS) alongside the topographical maps of the study area. Maps generated from this analysis met the minimum United States Geological Survey (USGS) and Congalton (1991) accuracy requirement of at least 85% and above. The classified temporal imageries were then exported back to ARCGIS 10.3 environment for polygonisation and calculation of the magnitude (areas) of various land uses and land covers, layout design and labelling. As illustrated by Table 1, a modified version of the Anderson *et al.,* (1976) land use and land cover classification schema was adopted by this study. The need to consistently discriminate land uses and land covers irrespective of seasonal variations informed the decision on the five land use and land cover classes used in the schema. This is further supported by Yang and Lo (2002) who notes that when undertaking digital image processing for land use and land cover variations, there is need to limit the number of land use and land cover classes used in the schema so as to avoid the spectral confusion which may occur due to several land uses and land covers having closer spectral responses.

Table 1. Land Use and Land Cover Classification Schema

	Classes	Description
i.	Urban Built-Up Areas/Open/Transitional Areas	Residential, commercial and services, industrial, transportation, communication and utilities. Open or Transitional areas are bare-lands which are exposed areas and quarries
ii.	Agricultural/Grass/Secondary Growth and Riparian Vegetation	Cropland, coffee plantations, horticultural farms, greenhouses, other agricultural crops, well – kept grass as well as the riparian vegetation
iii.	Forests	Evergreen forests, mixed forests with higher density of trees, little or no under storey vegetation
iv.	Rangeland and Shrubs	Sparsely distributed scrub species. Ground layer covered by grass. Species include *Acacia mellifera* and *Lawsonia inermis.* The shrubs constitutes perennial grass under storey, trees rarely above 5m, impoverished woodlands near the forests. Other dichotomy entails very sparsely distributed, low-lying scrub species. Usually less than 1m, typical species include *A. reficiens, Salvadora dendroides*, ground usually bare or covered by annual grasses.
v.	Water Bodies	Rivers, natural dams, reservoirs and waste water lagoons

Source: (Modified from Anderson *et al.,* 1976)

This study adopted Radiative Transfer Method of estimating urban surface temperature values from the satellite imageries of the years under consideration. Towards this end, radiometrically corrected Landsat TM imageries of the years 1988 and 1995 as well as Landsat ETM+ imageries of the years 2000, 2005, 2010 and 2015 (Bands 3, 4 and 6) were used. While the first step of Radiative Transfer Method involves the extraction of Digital Numbers (DNs) from the Thermal Infra-Red (TIR) imageries, the second step involved the conversion of DNs to spectral radiance using the below stated function.

$$L\lambda = 0.0370588 * DNs + 3.2 \quad (1)$$

Where: -

Lλ: The Spectral Radiance,

DNs: Digital Numbers

0.0370588: The Gain Constant (the gradient of the satellite's pre-launch radiance)

3.2: The Bias Constant (the spectral radiance of the DN at zero)

Conversions of the DNs to spectral radiance values were undertaken to correct the effects of atmospheric attenuations such as reflectance, absorption and scattering which create haziness in the imagery. For example, scattering creates adjacency effect in which radiance recorded for a given pixel partly incorporates the scattered radiance from the neighbouring pixels. The third step involved the calculation of the effective satellite temperature values of the imageries under consideration using the below stated function.

$$TEs = (K_2)/L_n \{(K_1/ L\lambda) +1\} \quad (2)$$

Where: -

TEs: Effective satellite temperature values

Lλ: The Spectral Radiance

L_n: Natural Logarithm

K_2 and K_1: The calibration constants whose values are

	Landsat TM	Landsat ETM+	
K_1	607.76	666.09	mWcm^2
K_2	1260.56	1282.71	K

The fourth step involved the calculation of the Normalized Differential Vegetative Indexes (NDVIs) using the below stated function.

$$NDVI= (R\ Band\ 4-R\ Band\ 3)/(R\ Band\ 4+R\ Band3) \quad (3)$$

Where: -

NDVI: Normalized Differential Vegetative Index

R Band 4: Land Surface Reflectance in the Near Infra-Red Band

R Band 3: Land Surface Reflectance in the Visible Bands.

The fifth step involved the calculation of the Emissivity (ε) values from the NDVIs using the below stated function.

$$Emissivity\ (\varepsilon) = 1.0094 + 0.047 * L_n(NDVI) \quad (4)$$

Finally, surface temperature values (Ts) were computed using the below stated function.

$$Ts = (TEs)/\{1+ [\lambda * (TEs/\rho)]\ L_n\varepsilon\} \quad (5)$$

Where:-

Ts: Surface Temperatures Values

TEs: Effective satellite temperature values

L_n: Natural Logarithm

ε: Emissivity Value

λ: The wavelength of the emitted radiance = 11.5μm (Markham and Baker, 1985);

ρ: hc/σ = 1.438 x 10^2 mK;

σ: Stefan Boltzmann constant (5.67 x 10^-8Wm^-2K^4),

h: Planck's constant (6.626 x10^-34Js)

c: 2.998 x 10^8 m/s.

While the classified land uses and land covers for the years under consideration are presented inform of maps, information on the magnitude of same is tabulated. A graph is used to present the temporal trends of land uses and land covers. The information on surface temperature variations and the average temperature values in the city for the years under consideration is presented in form of surface temperature maps and a table respectively. Determination of the relationship existing between urbanisation, global warming and climate change is undertaken through the establishment of the strength of the relationship existing between surface temperature values, the size of land under built-up, open and transitional areas and the size of land under vegetation cover. This is done through multivariate regression analysis, computation of correlation coefficient (r), *t*-test and the Analysis of Variance (ANOVA). The main Softwares used in this study were ILWIS Academic 3.6, ARCGIS 10.3, Microsoft Excel 2010 and Statistical Package for the Social Scientists (SPSS) Softwares.

4. Findings and Discussions

Land Uses and Land Covers of Nairobi City for the Period between 1988 and 2015

The classified land use and land cover maps of Nairobi for the years 1988, 1995, 2000 2005, 2010 and 2015 are shown in Figures 2, 3, 4, 5, 6 and 7 respectively. While quantification of land uses and land covers is summarized in Table 2, trends of the same are presented in Figure 8. This study reveals that the area of the city under built-up, open and transitional land cover have increased from 73.08 km^2 in the year 1988 to 228.65 km^2 in the year 2015. While agricultural, grass, secondary growth and riparian vegetation which occupied 126.82 km^2 of the city in the year 1988 have marginally increased to 189.73 km^2 in the year 2015; forest cover have shown mixed gains and loss. In the year 1988, the area of the city under the forest cover was 59.63 km^2. This increased to 122.41 km^2 in the year 1995 and thereafter declined by approximately 52% reaching 63.63 km^2 in the year 2000. The decline is attributed to the indiscriminate extraction of forest resources and clearance of the same for urban developments which characterised the periods between the years 1995 to 2002. This situation was reversed in the year 2003 when the new government re-emphasised and re-energised strategies geared towards increasing the forest cover in the country. Such strategies included the degazettement and clearance of illegal structures within the forest reserves. This has since made the area of the city under forest cover to gradually increase from 63.63 km^2 in the year 2000 to 93.44 km^2 in the year 2015. The area of the city under rangeland and shrub vegetation cover have steadily declined from the year 1988 when it covered 453.99 km^2 of the city to 200.30 km^2 in the year 2015.

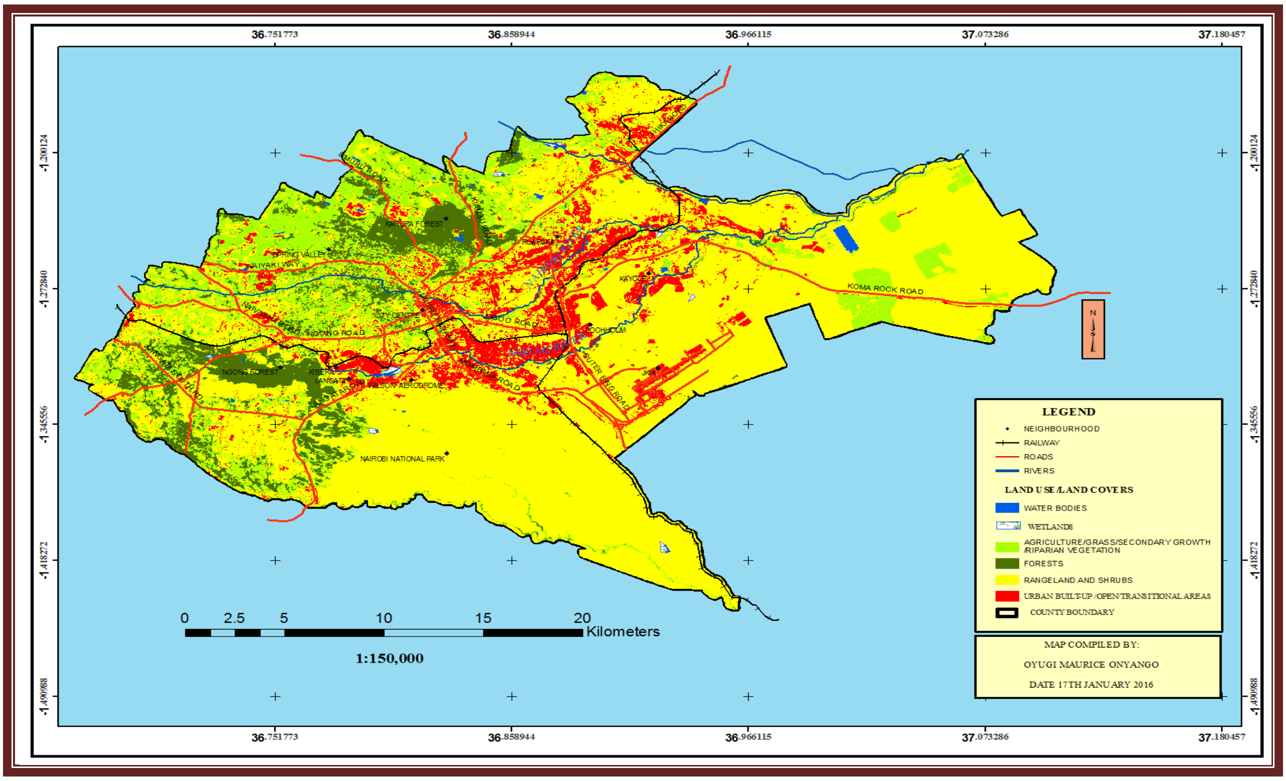

Figure 2. Land Use and Land Cover Map of Nairobi for the Year 1988

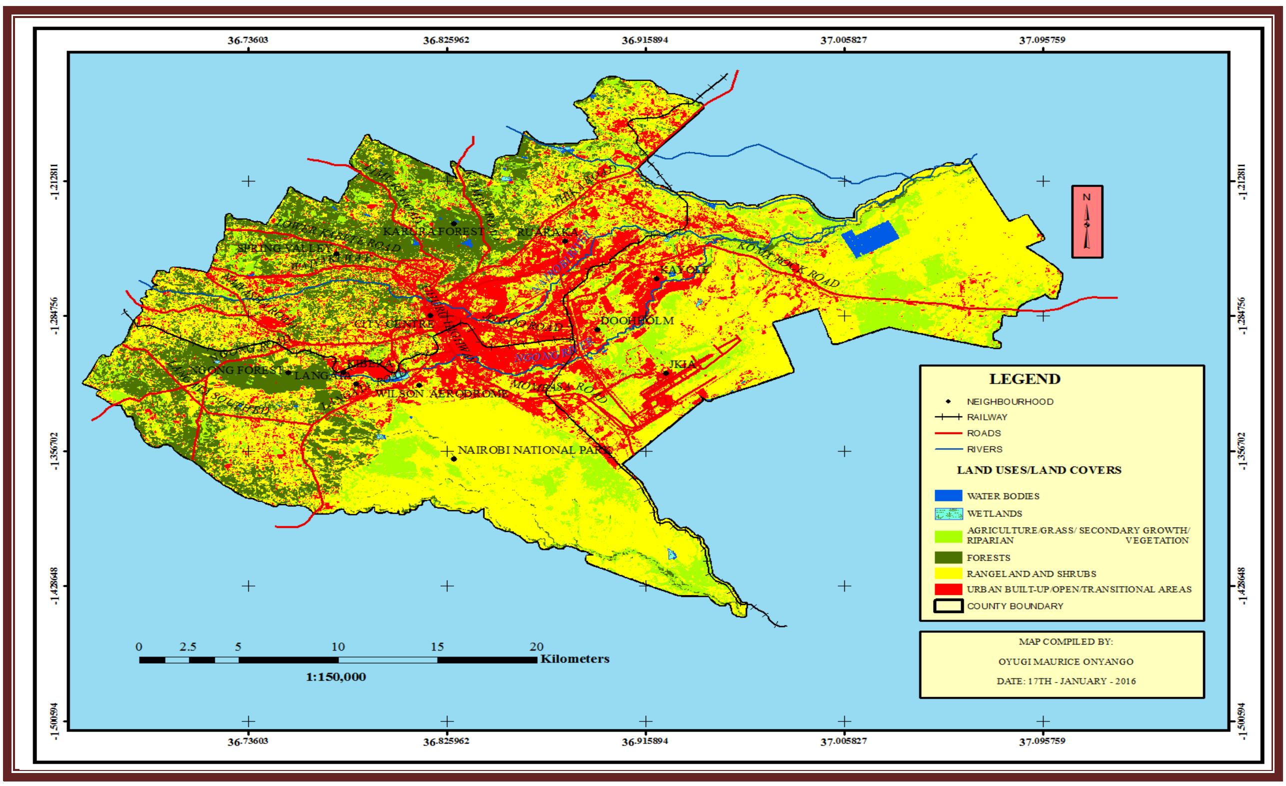

Figure 3. Land Use and Land Cover Map of Nairobi for the Year 1995

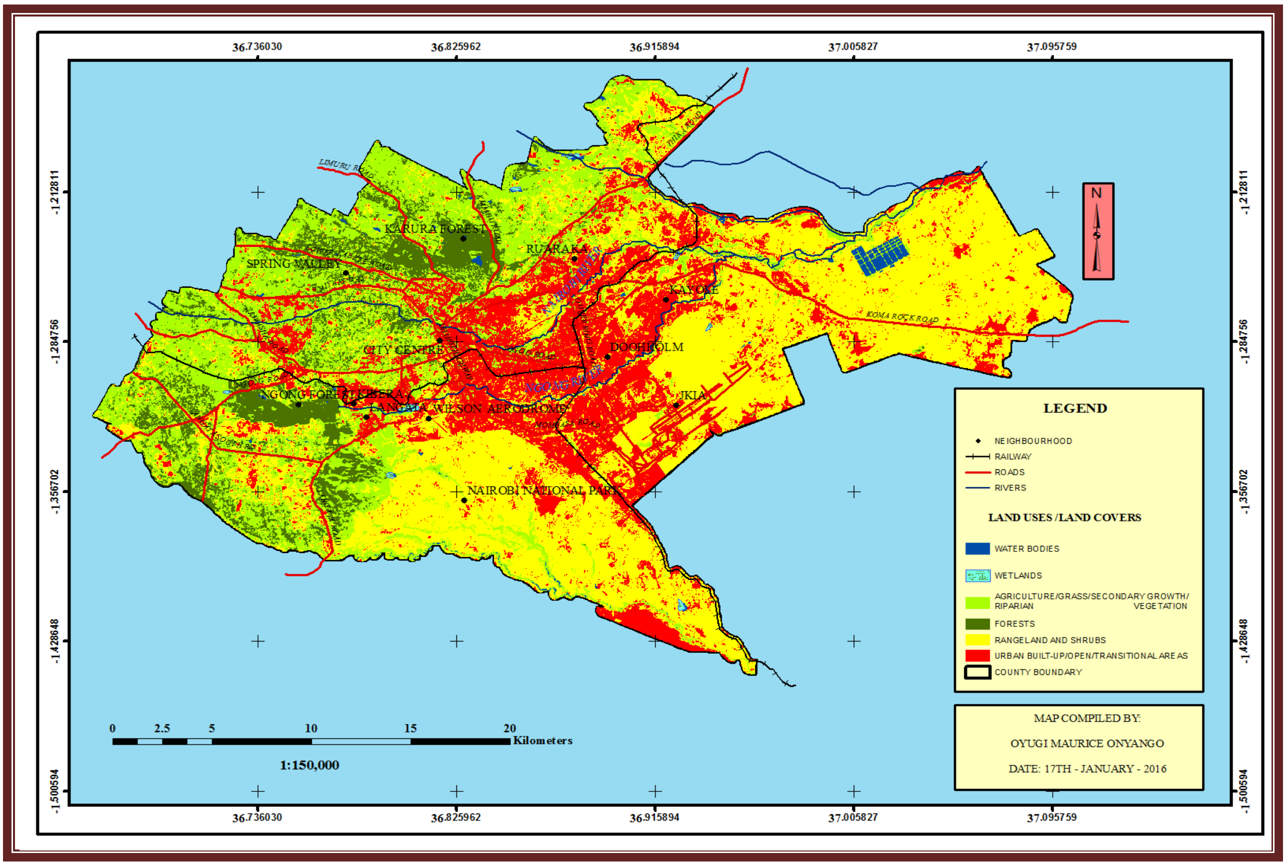

Figure 4. Land Use and Land Cover Map of Nairobi for the Year 2000

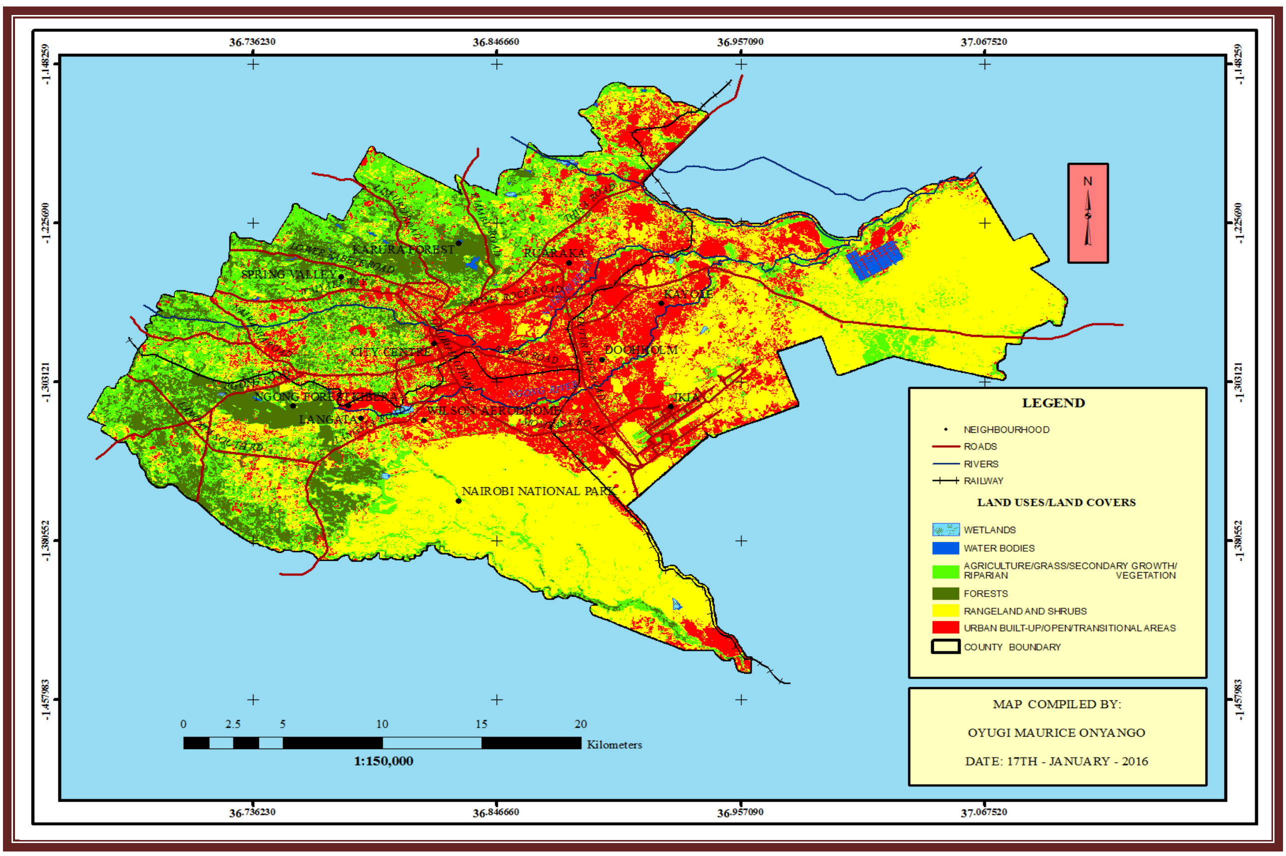

Figure 5. Land Use and Land Cover Map of Nairobi for the Year 2005

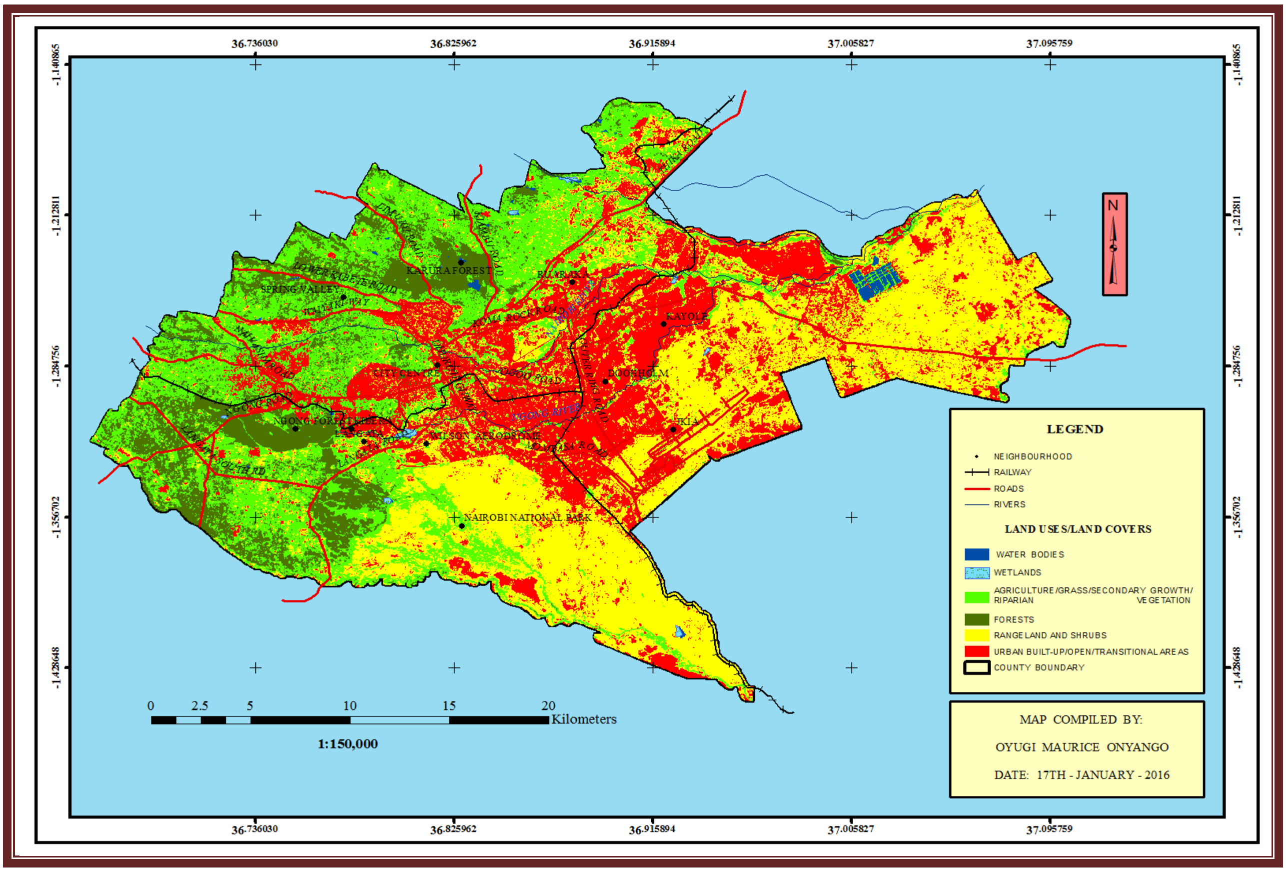

Figure 6. Land Use and Land Cover Map of Nairobi for the Year 2010

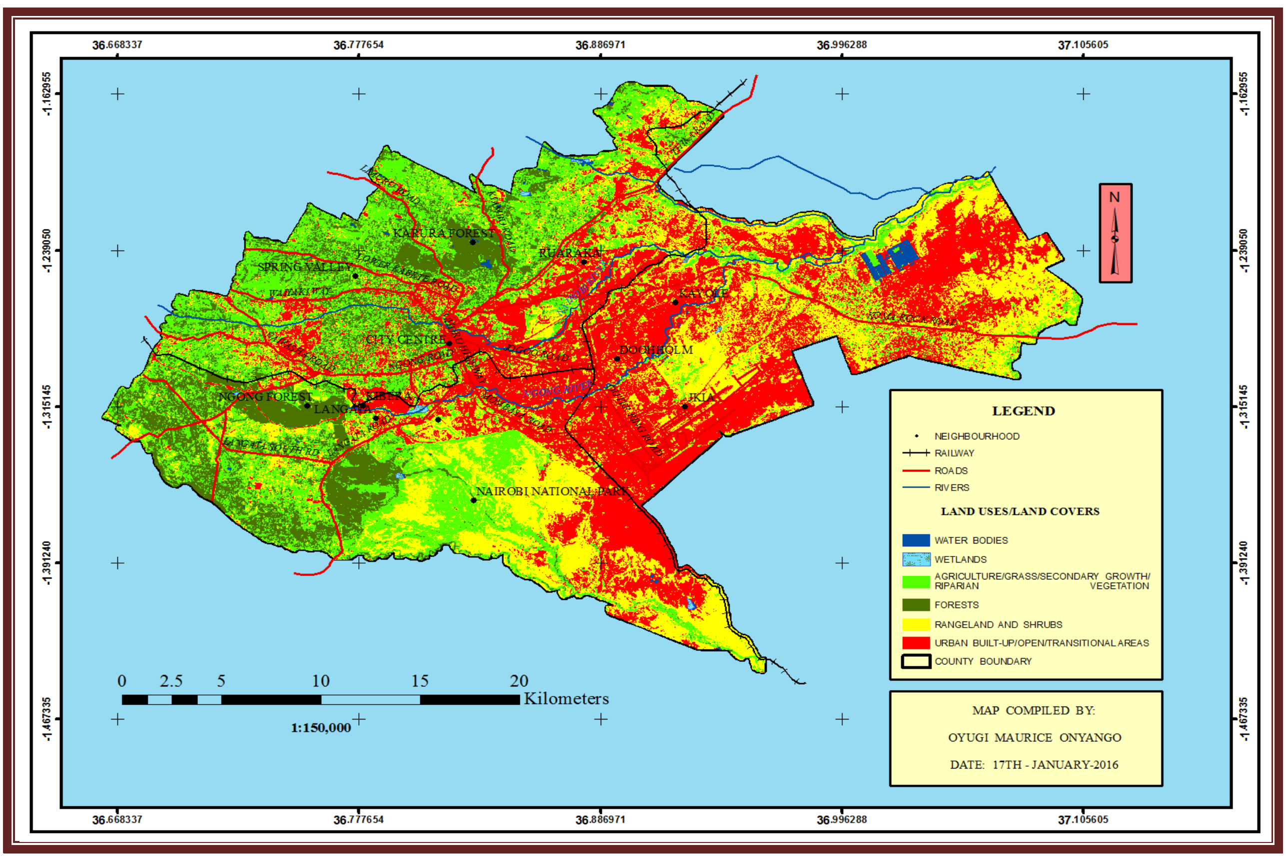

Figure 7. Land Use and Land Cover Map of Nairobi for the Year 2015

Table 2. Land Use and Land Cover Types in Nairobi City between the Years 1988 to 2015

Land Use and Land Cover Classes		Years											
		1988		1995		2000		2005		2010		2015	
		Area (Km^2)	Percentage	Area (Km^2)	Percentage	Area (Km^2)	Percentage	Area (Km^2)	Percentage	Area (Km^2)	Percentage	Area (Km^2)	Percentage
i	Agriculture /Grass/ Secondary Growth/ Riparian Vegetation	126.82	17.71	101.12	14.12	176.76	24.68	143.03	19.97	190.75	26.63	189.73	26.49
ii	Water Bodies	2.70	0.38	4.72	0.66	4.84	0.68	3.62	0.51	3.04	0.42	4.09	0.57
iii	Urban Built-Up/Open/ Transitional Areas	73.08	10.20	124.36	17.36	155.20	21.67	175.19	24.46	183.97	25.69	228.65	31.93
iv	Forests	59.63	8.33	122.41	17.09	63.63	8.88	79.14	11.05	83.19	11.62	93.44	13.05
v	Rangeland and Shrubs	453.99	63.39	363.61	50.77	315.79	44.09	315.23	44.01	255.25	35.64	200.30	27.97
TOTAL		**716.22**	**100.00**	**716.22**	**100.00**	**716.22**	**100.00**	**716.22**	**100.00**	**716.22**	**100.00**	**716.22**	**100.00**

Source: (Researcher, 2017)

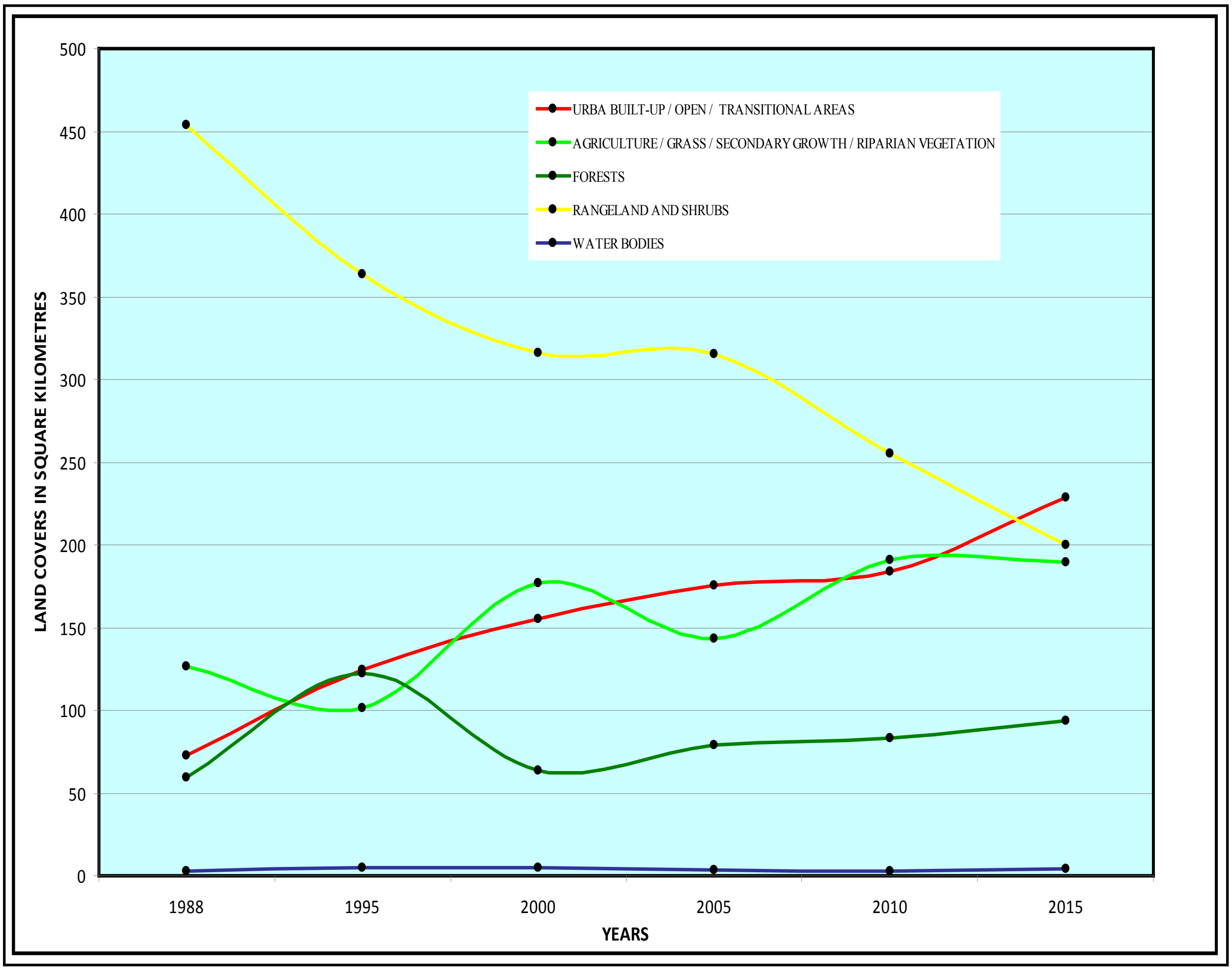

Figure 8. Land Use and Land Cover Change Trends in Nairobi City between the Years 1988 to 2015 [**Source:** (Researcher, 2017)]

Major land use and land cover conversions took place within the study period. Notably, there has been a marked decline in rangeland and shrubs as well as forest covers which is attributed to the expansion of the urban built-up, open and transitional areas or the urban sprawl. The steady decline in the ratio of the city under vegetation cover to the area under urban built-up, open and transitional lands have significant implications on the urban surface temperature values, air pollution levels and other environmental quality parameters. However, the spatial pattern of the urban sprawl or the expansion of the urban built-up, open and transitional areas exhibits variations. The expansion has not been even in all the directions of the city for it has occurred relatively faster but with discontinuous patches of built-up, open and transitional areas in zones along Thika, Kangundo, Koma-Rock and Mombasa Roads. This has been occasioned by the distribution of the transportation arterials and the *ad hoc* nature of planning which has characterised the city over the years. The *ad hoc* nature of planning has encouraged rapid revisions of land use zoning policies and regulations (minimum plot sizes, plot ratios and coverages), land speculations as well as land use and land cover changes. While the revisions have tended to favour increased development densities, conversions of productive agricultural lands to residential, industrial and commercial developments, the distribution of transportation arteries have significantly determined the nature, magnitude, trend, pattern and rate of urban development and the distribution of economic activities. This has contributed to the emergence of a hybrid of concentric and sector models of urban spatial structure characterised by the city having a major Central Business District from which satellite Central Business Districts revolve around.

The urban agriculture in Nairobi can be categorised as either small-scale crop gardening or the peri -urban agriculture. While the small scale gardens which require limited spaces are found along roadsides, within flood plains and high density residential zones of the central parts of the city, peri-urban agriculture are established where land holdings are relatively large enough to accommodate cultivation and livestock rearing. The decline in the percentage of land under agriculture in the study period is partly attributed to the population growth in the peri-urban areas which leads to land fragmentation to acreages which are not agriculturally viable. This necessitates conversion of the agricultural land to urban built-up users such as residential, industrial and commercial developments. This study further reveals marked encroachment and degradation of the gazetted and protected areas such as the forests and the Nairobi National Game Park by the urban built-up developments and other anthropogenic activities such as grazing. This has reduced the forest covers to either rangeland and shrubs or open and transitional areas. The anthropogenic encroachments have over the years affected water supply, the availability of wildlife and overall environmental quality of the city.

As earlier stated, surface temperature values of the city for different years under consideration were computed from the satellite imageries of the same. To corroborate the relationship existing between urbanisation, global warming and climate change, average surface temperature values of the city for the years under consideration were computed alongside the size of land under built-up, open and transitional areas as well as the size of land under vegetation cover for years under consideration as illustrated by Table 3. Figures 9 to 14 corroborate that Nairobi's surface temperature variations broadly manifesting in four surface temperature zones namely; the northern and western, southern, eastern and central zones is influenced by the interactions and variations in vegetation types and density, urban form, topographical and pedological base of the city. The red volcanic soils and higher topography which characterises the northern and western parts of the city are rich in nutrients and humus contents thus support healthy indigenous and exotic vegetation growths which are effective moderators of surface temperature values. Contrary to the above, southern and eastern parts of the city which are characterised by low lying plains, undulating topography and black cotton clay soils with low nutrient contents supports sparse vegetations such as the disturbed bushes, shrubs, perennial grasses and under storey trees which are inadequate moderators of surface temperature values. Therefore, the presence of the forest reserves (Ngong and Karura forests) and higher topographies to the northern and western parts of the city, coupled with low development densities characterising the neighbourhoods have acted in concert towards the achievement of lower surface temperature values in the zones as compared to higher surface temperature values being experienced in the southern and eastern parts of the city which are characterised by low lying plains, undulating topography, black cotton soils, sparse vegetation cover, high development densities and dominance of land uses such as transportation, industrial developments and quarries which enhances thermal values. The central part of the city which is characterised by mixtures of red volcanic and black cotton clay soils supports moderate vegetation growth thus the zone experiences moderate surface temperature values.

The bivariate relationship existing between the size of land under built-up, open and transitional areas and the surface temperature values is a very strong positive relationship corroborated by a correlation coefficient (r) value of 0.948 and a calculated *t*-value of 5.94 compared to a critical *t*-value of 2.78. While the calculated F-value of the relationship existing between the two variables is 35.284, the critical F-value is 7.71. This confirms that the relationship existing between the size of land under built-up, open and transitional areas and the surface temperature values in the city is significantly strong and is not occurring by chance. Similarly, the relationship existing between the size of land under vegetation cover and the surface temperature values presents a significant negative relationship evidenced by a correlation coefficient (r) value of -0.946 and a calculated *t*-value of -5.843 compared to a critical *t*-value of either -2.78 or 2.78. The calculated and the critical F-values for the relationship are 34.136 and 7.71 respectively. This confirms that the relationship existing between the size of land under vegetation cover and the surface temperature values is significantly strong and is not occurring by chance.

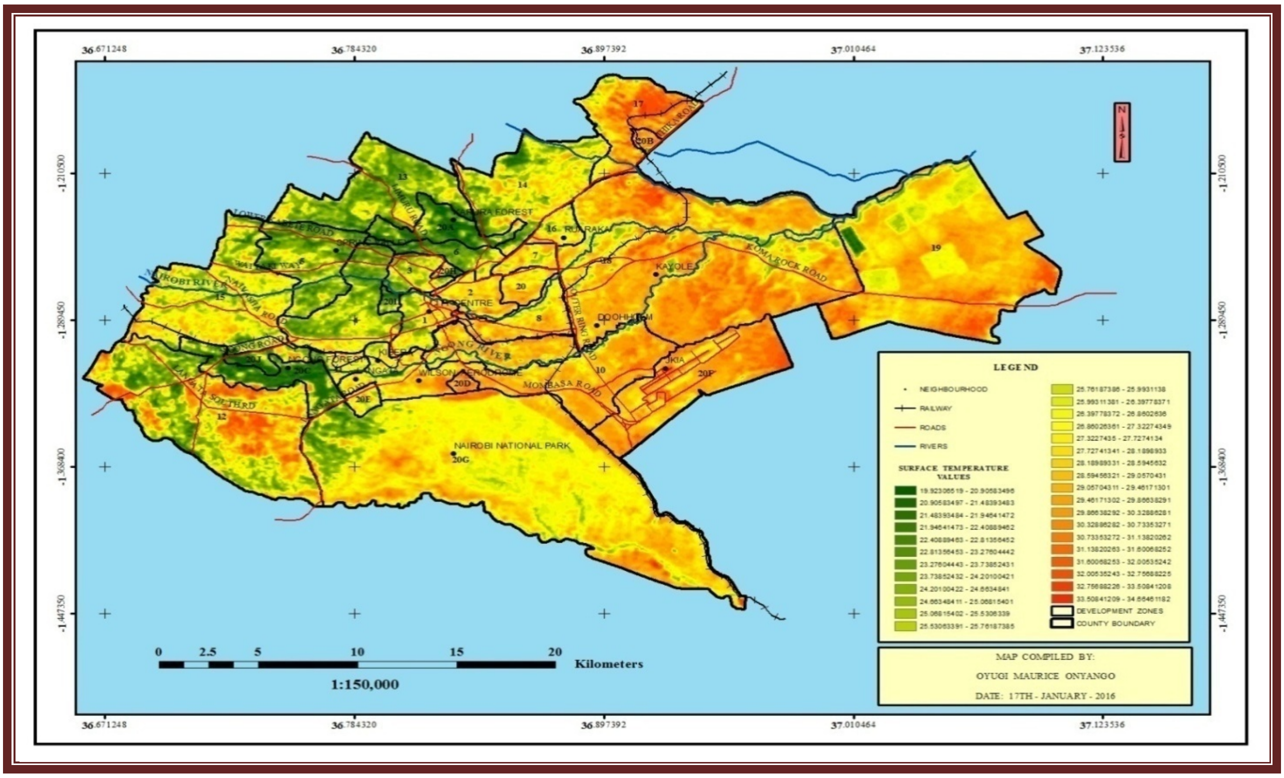

Figure 9. The Spatial Distribution of the Surface Temperature Values of Nairobi City in the Year 1988

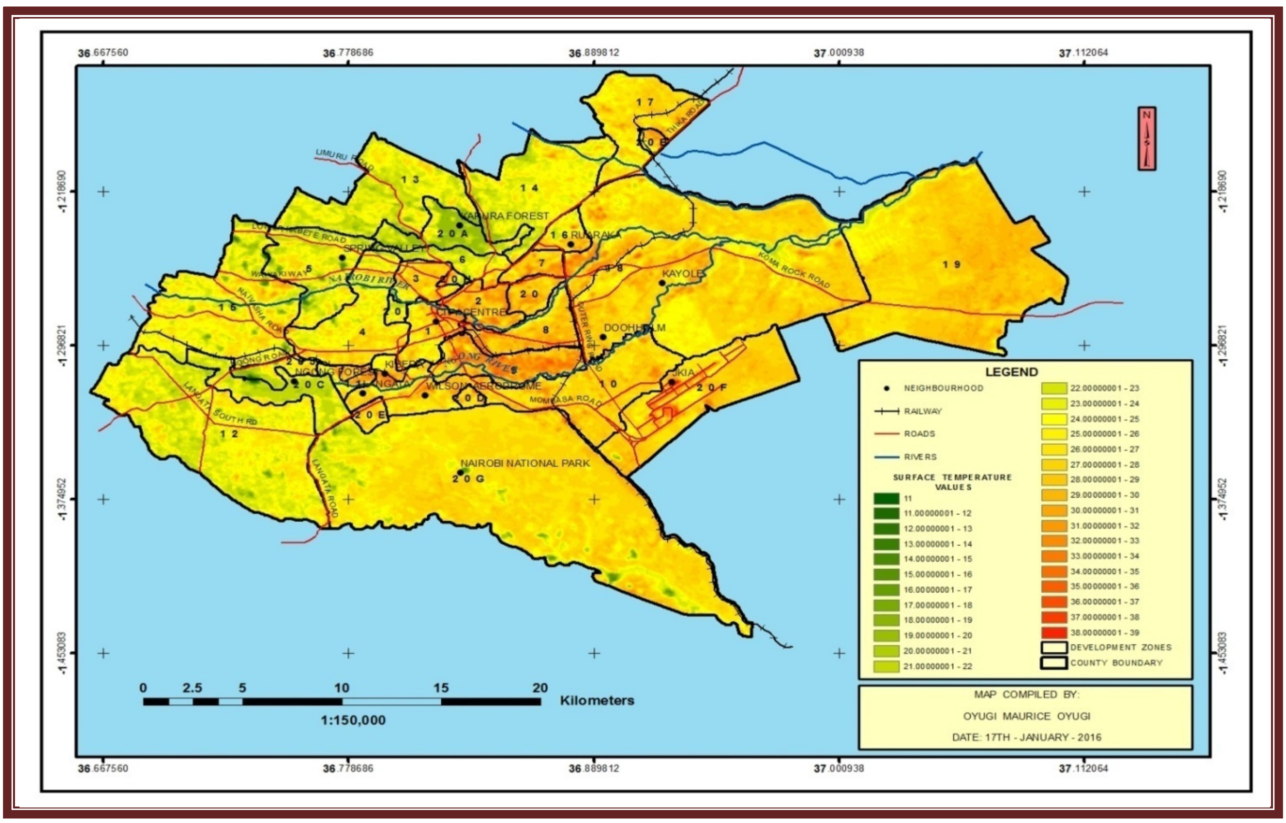

Figure 10. The Spatial Distribution of the Surface Temperature Values of Nairobi City in the Year 1995

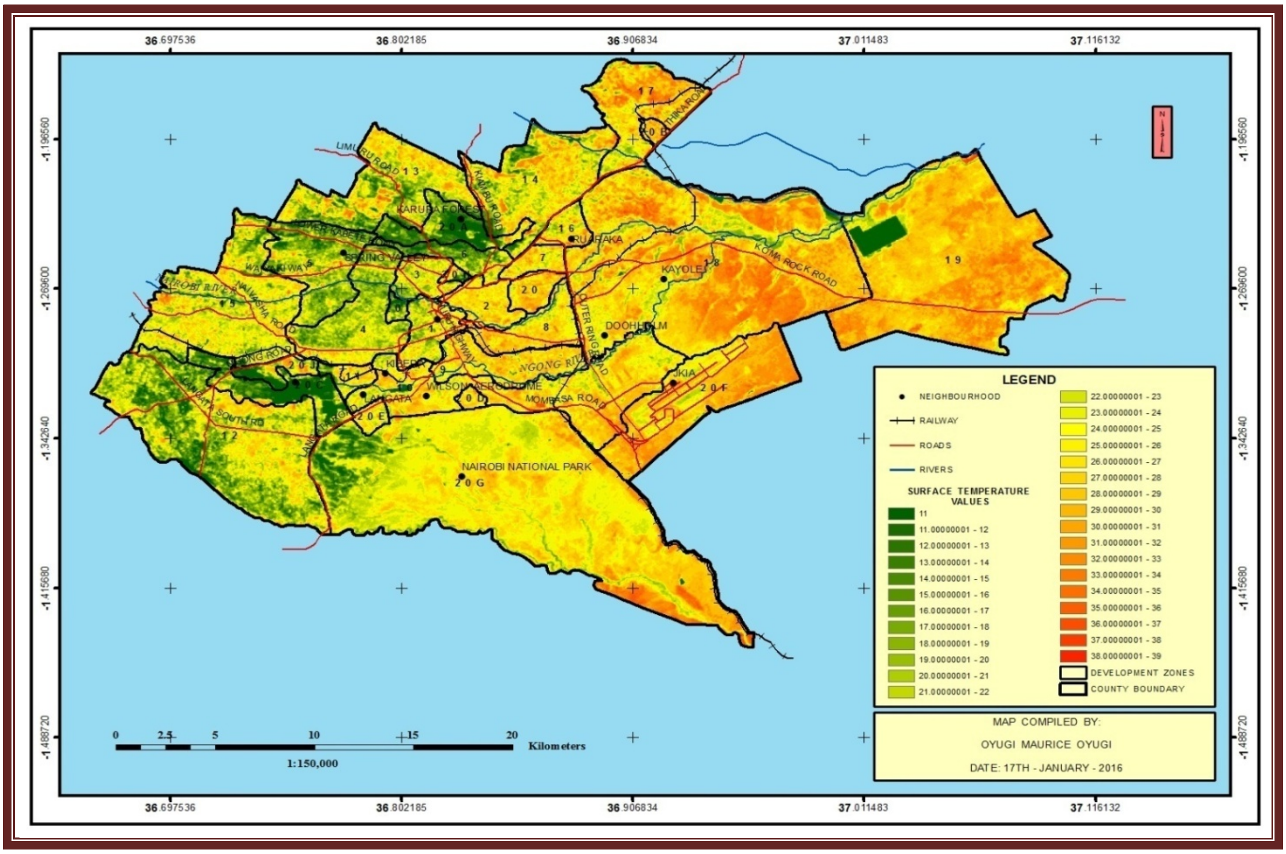

Figure 11. The Spatial Distribution of the Surface Temperature Values of Nairobi City in the Year 2000

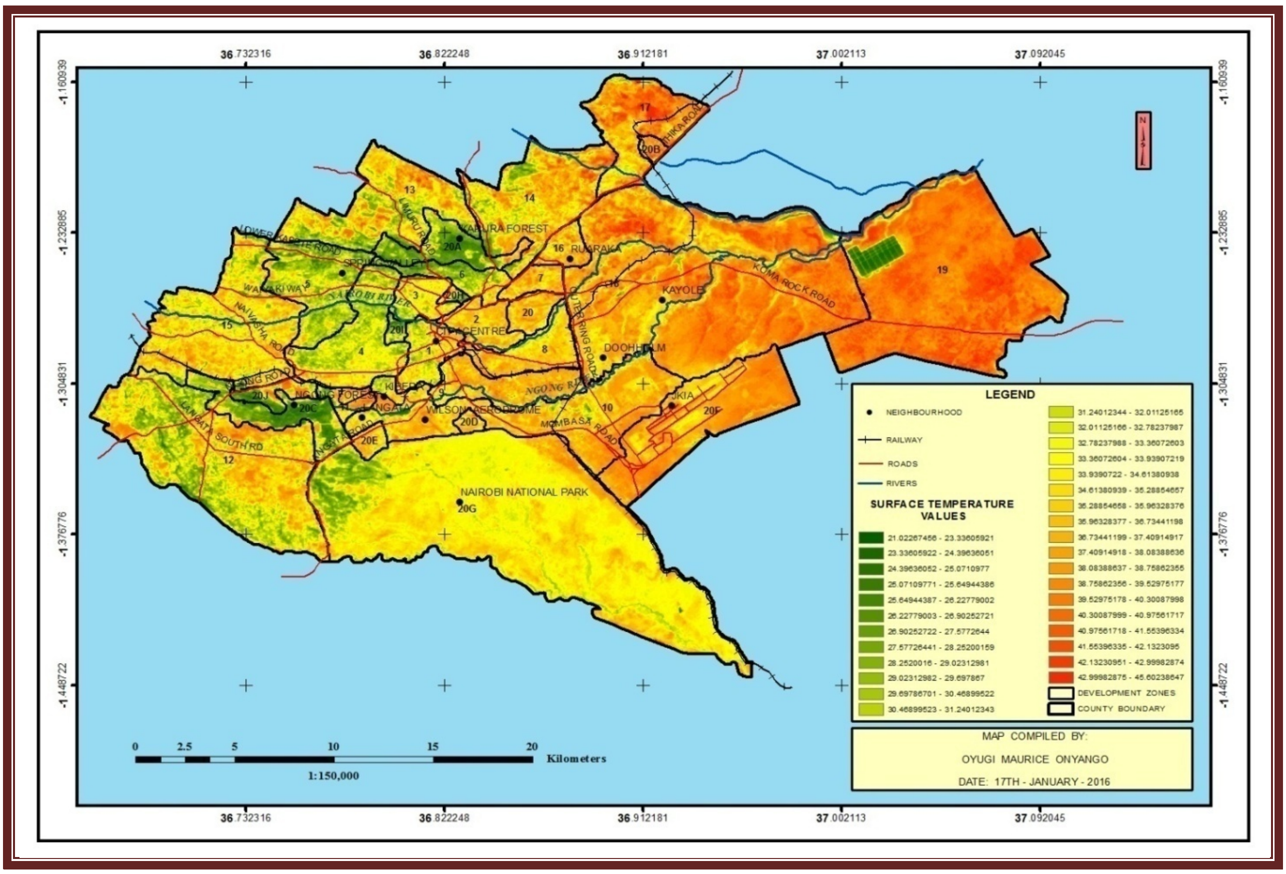

Figure 12. The Spatial Distribution of the Surface Temperature Values of Nairobi City in the Year 2005

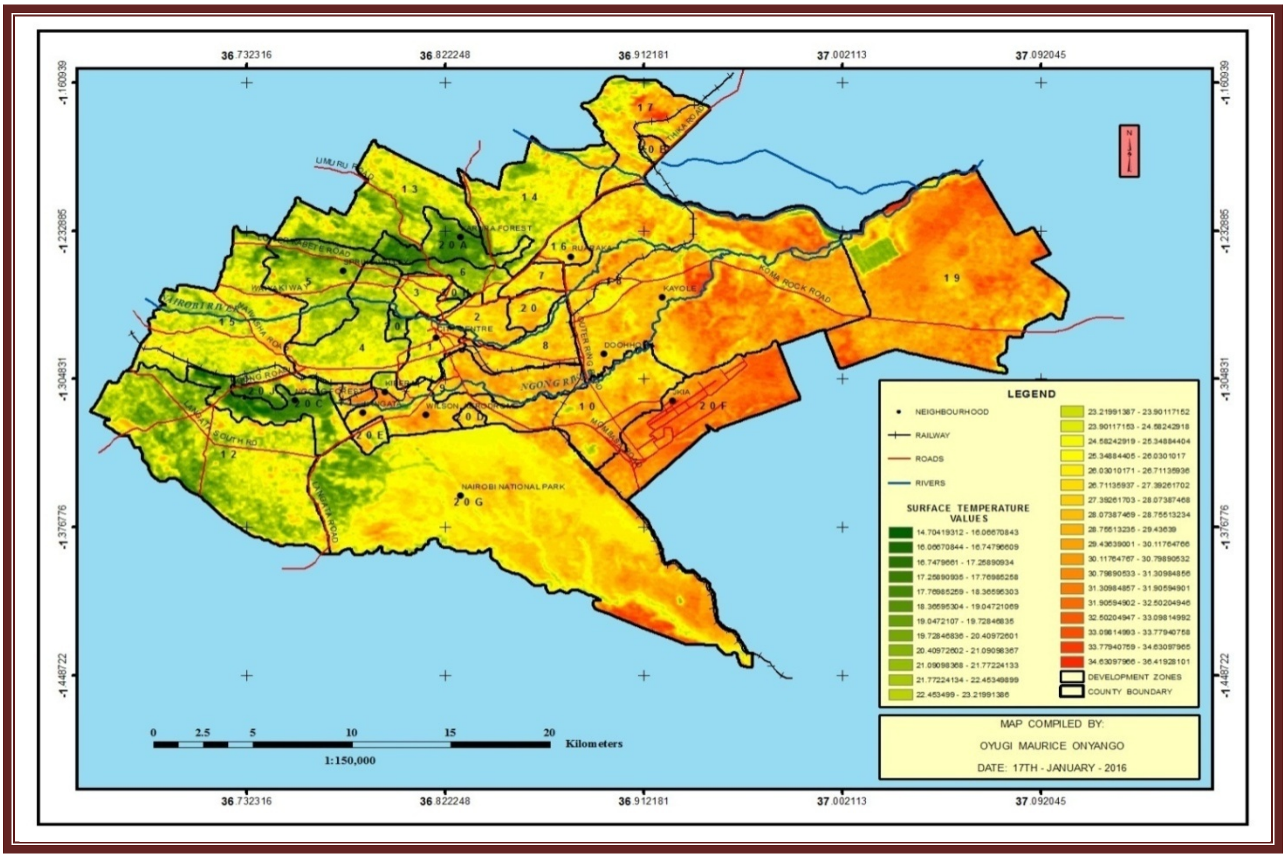

Figure 13. The Spatial Distribution of the Surface Temperature Values of Nairobi City in the Year 2010

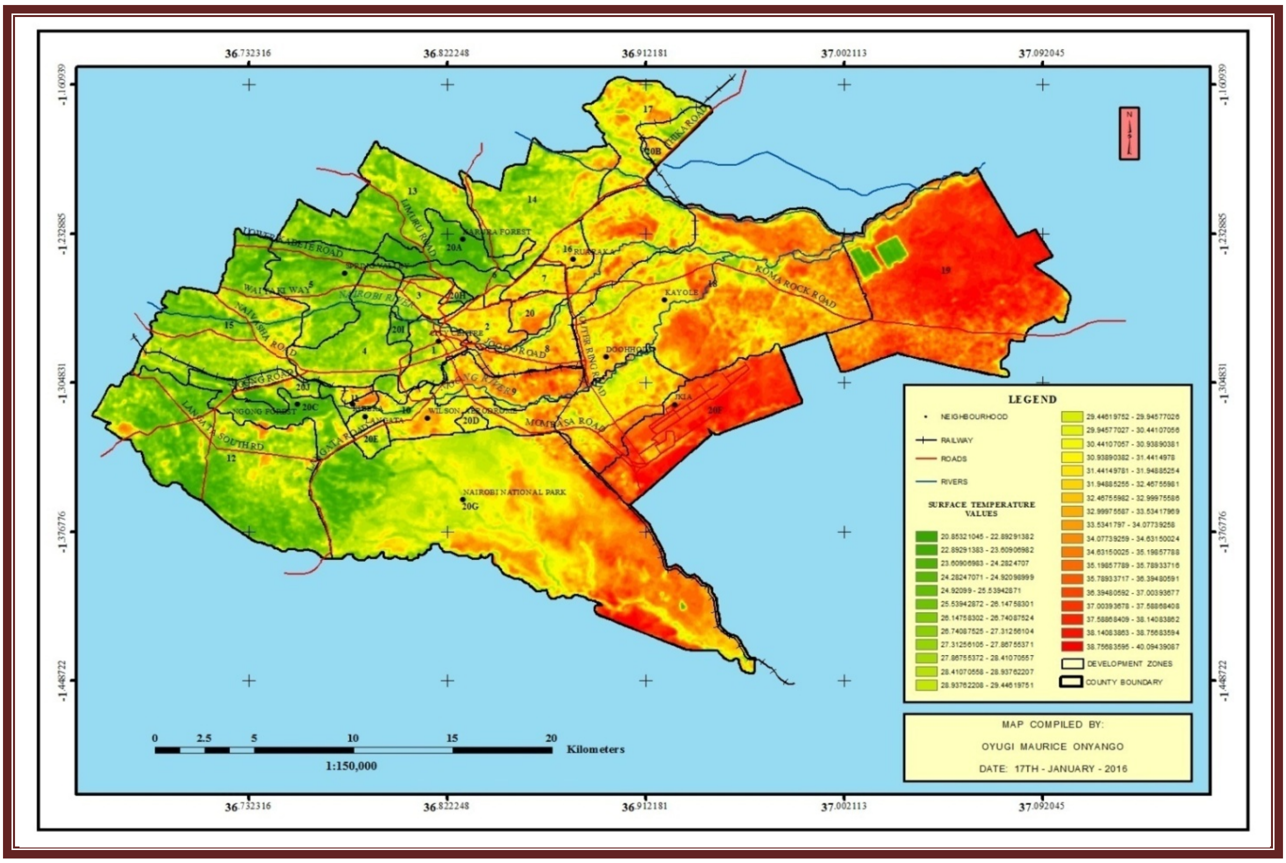

Figure 14. The Distribution of the Surface Temperature Values within Nairobi City in the Year 2015

Table 3. Average Surface Temperature Values, Land Use and Land Cover Areas

Years	Average Surface Temperature Values (°C) (Y)	Urban Built-Up, Open and Transitional Areas (km^2) (X_1)	Vegetation Cover Areas (km^2) (X_2)	Total Area (km^2)
1988	24.4	73.076	640.45	716.22
1995	25.5	124.36	587.14	
2000	28.3	155.20	556.18	
2005	28.7	175.19	537.40	
2010	29.4	183.97	529.20	
2015	29.7	228.65	483.47	

Source: (Researcher, 2017)

The multivariate model representing the relationship existing between the surface temperature values, the size of land under built-up, open and transitional areas and the size of land under vegetation cover is represented by the below stated function.

$$\acute{Y} = 0.286X_1 + 0.247X_2 - 154.254 \quad (6)$$

Where: -

$\acute{Y}$ = The estimated Average Surface Temperature Value for a given year

X_1 = Size of land under Urban Built-Up, Open and Transitional Areas

X_2 = Size of Land under Vegetation Cover

Other statistics for the above stated relationship are as follows:-

t_1 = The calculated *t*-value attributed to the size of land under Built-Up, Open and Transitional Areas which is 6.27

t_2 = The calculated *t*-value attributed to size of land under vegetation cover which is 5.42

t_3 = The calculated *t*-value attributed to the error term (constant) which is -4.75

F = The calculated F-value of the relationship which is 14.673

The analysis confirms that in concert, the size of land under built-up, open and transitional areas is the most significant determinant of the urban surface temperature values relative to the size of land under vegetation cover. However, the significance of the calculated *t*-value attributed to the error term (-4.75) in the model implies that apart from the size of the urban land under built-up, open and transitional areas and the size of the same under vegetation cover, other variables which are not considered by this relationship and/or study significantly explains the spatial distribution of the surface temperature values within the city. The above findings is supported by Oke (1987) who notes that alterations of urban development densities, land uses and surface materials through increased building configurations and other man-made structures replacing vegetation cover, makes surfaces impermeable and dry with a corresponding increase in surface temperature values. This is because building materials commonly used for pavements and roofing has higher thermal energy absorption and retention capacity as compared to open spaces and vegetation cover. Further to the above, apart from urban skyscrapers increasing the efficiency with which urban areas are heated through provision of multiple surfaces for the reflection and absorption of the solar energy, they also attenuate wind velocity which inhibits the cooling effects (heat diffusion) of the same. The thermal heat from transportation and industrial plants also contributes to urban heat island effects (Zhao and Zeng, 2002; Kubota and Ossen, 2008; Artis and Carnahan, 1982; Brovkin, 2002; Weng *et al.,* 2004).

Through a combination of shading, evaporative cooling effects and photosynthetic processes, vegetation mitigates urban neighbourhoods against heating and polluting effects generated by the urban developments. While the evapo-transpiration process enables the vegetation to moderate the surface temperature values, photosynthetic processes in vegetations mitigate the greenhouse effects. Therefore, an urban development which diminishes natural vegetation cover lowers the ability of the environment to cool itself and to reduce the concentrations of the air pollutants, which has profound effect on urban environmental quality. This makes vegetation density an imperative urban morphological parameter which directly determines the spatial distribution of the surface temperature values, air quality and overall urban environmental quality.

5. Conclusions

This study has established that the built-up, open and transitional developments as well as vegetation cover determines the spatial distribution of surface temperature values in the city with varying levels of significance. Of the two variables considered by the study, the built-up, open and transitional development is the most significant variable influencing the spatial distribution of the surface temperature values in the city. However, if the significance of the error term in the model explaining the relationship existing between surface temperature values, the built-up, open and transitional developments and the vegetation cover has to be minimised then alongside with the stated variables, inclusion of other parameters such as topography, pedology, rainfall pattern and amount, slope, aspects and wind velocity among others should be considered in aiding the building of a comprehensive model explaining the spatial distribution of the surface temperature values in the city. This study confirms the theoretical postulations that the relationship existing between the surface temperature values, land uses and land covers of a city is hinged on intervening, indirect and direct variables such as the urban population distribution, pedology, topography, wind velocity, slope, aspects, climate (rainfall pattern and amount) of the region where the city is located, vegetation, development densities, land uses, street and building configurations (Sundarakumar *et al*., 2011; Mahmood *et al.,* 2010; Tan *et al*., 2010; Gottdiener and Budd, 2005).

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