Journal of Geographic Information System, 2017, 9, 763-776
http://www.scirp.org/journal/jgis
ISSN Online: 2151-1969
ISSN Print: 2151-1950

# Impact of Land Use/Land Cover Change on Surface Temperature Condition of Awka Town, Nigeria

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**How to cite this paper:** Nzoiwu, C.P., Agulue, E.I., Mbah, S. and Igboanugo, C.P. (2017) Impact of Land Use/Land Cover Change on Surface Temperature Condition of Awka Town, Nigeria. *Journal of Geographic Information System*, **9**, 763-776.
https://doi.org/10.4236/jgis.2017.96047

**Received:** June 29, 2017
**Accepted:** December 26, 2017
**Published:** December 29, 2017



## Abstract

This paper is aimed at identifying the land use/cover types in Awka in relation to their temporal dynamics, the extent of land use change in the city and effects of land use change on surface temperature. Multitemporal Landsat TM, $ETM^+$ and OLI imageries were obtained at 15 years interval for 1986, 2000 and 2015 respectively. Image classification was conducted using supervised classification method. The result showed that built-up area has been on the increase, expanding from 9.55 sqkm in 1986 to 21.3 sqkm in 2000 and 21.45 sqkm in 2015. Cultivated lands have maintained a steady decline since 2000 having lost about 3.29 sqkm of its area. Similarly, vegetation, made up of dense, savanna and riparian, has been on a decline from a total of 33.69sqkm in 1986 to 21.407 sqkm losing about 12.29 sqkm of its area and increased by a mere 4.07 sqkm in 2015. These alterations had given rise to an average increase of 2.2˚C in surface radiant temperature. This study recommends that relevant government planning agencies (ACTDA, ASHDC, etc.) should factor in the concept of greening and green spaces into their development policies and strategies to ensure that fair, conducive microclimate and sustainable environment is maintained in the Awka urban area.

## Keywords

Landsat, Land Use/Cover, Supervised Classification, Multitemporal, Land Surface Temperature

## 1. Introduction

The phenomenon of land use change has become a vital and central component of monitoring environmental changes and managing resources [1] [2]. Human activities are many and varied; considering the geometric rise in global population, there is need for more settlements, roads, increased agricultural production, increased demand for food and shelter, changes in life style etc. which has invariably led to increased encroachment on natural vegetation. The consequence of this change is characterized by the various land use types that dominate many human habitations resulting to changes in land cover characteristics. As these activities combine to alter the geometry of the earth's surface, they have enormous ramifications such as in inadvertent climate modifications resulting from surface vegetal cover removal peculiar to urbanization and agricultural purposes [3].

The presence of vegetation within a locality ensures ecosystem sustainability and services such as prevention of soil erosion, reduction in soil and nutrient loss and maintenance of hydrological cycles [4] [5]. Consequently, [6] wrote that land use change has become one of the major determinants of environmental vulnerability within the human environment system; besides the direct impact on the spatial extent of ecosystems through deforestation, fragmentation etc., land use change modifies the spatial configuration of different land use types [5]. Similarly, the unprecedented changes in land, its use and cover characteristics affect the structure and floristic pattern and composition of a region [5] and have been acknowledged to decrease species richness and diversity worldwide [4].

Changes in land use from temperate forest to cropland, from tropical forest to savanna, from grassland to desert or from rural to urban area alter the microclimate [7]. Microclimatic changes are significant because humans live within the microclimate, under trees and among grasses [7]. The most significant of this change are variations in thermal characteristics of the area. Thus, built up areas tend to have land surface temperatures (LST) higher than surrounding suburban environment [8] [9]; and these thermal differences are contributing to the development of microclimatic condition otherwise referred to as the urban heat island (UHI) [1] [2] [10] [11]. Numerous studies [9]-[14] which have studied the relative effects of land use/Land cover change (LULCC) on LST have always found a positively correlated result with imperviousness.

More so, the removal of vegetation cover often leads to the adjustment in local water balance because the interception role of the canopy is lost, evapo-transpiration is changes or reduced [11] [15] runoff may be increased and radiation budget [2] may be upset by prescribing new surface geometry and albedo. These and numerous other effects reported in researches [1] [8] [9] [10] [11] [14] [16] [17] [18] stressed the fact that man has very likely destroyed vegetation cover over vast areas for various purposes during the last few decades thereby leading to modification of climate [3] [19] as energy and mass balances are unfavourably altered, allowing the soil to be destroyed and desertification to set in most places.

Consequently, it has become imperative that we detect LULC changes accurately at appropriate scales, and in a timely manner so as to better understand their impacts on climate and provide improved understanding on other environmental implications.

## 2. Materials and Methods

### 2.1. Study Area

Awka town is located in the South–Eastern part of Nigeria and in the eastern part of Anambra State.

It covers parts of Awka South Local Government and some parts of Awka North. It is bounded by Latitudes 6˚11'N and 6˚17'N and longitude 7˚02'E and 7˚08'E (**Figure 1**). It has an estimated land area of 60.2 km$^2$.

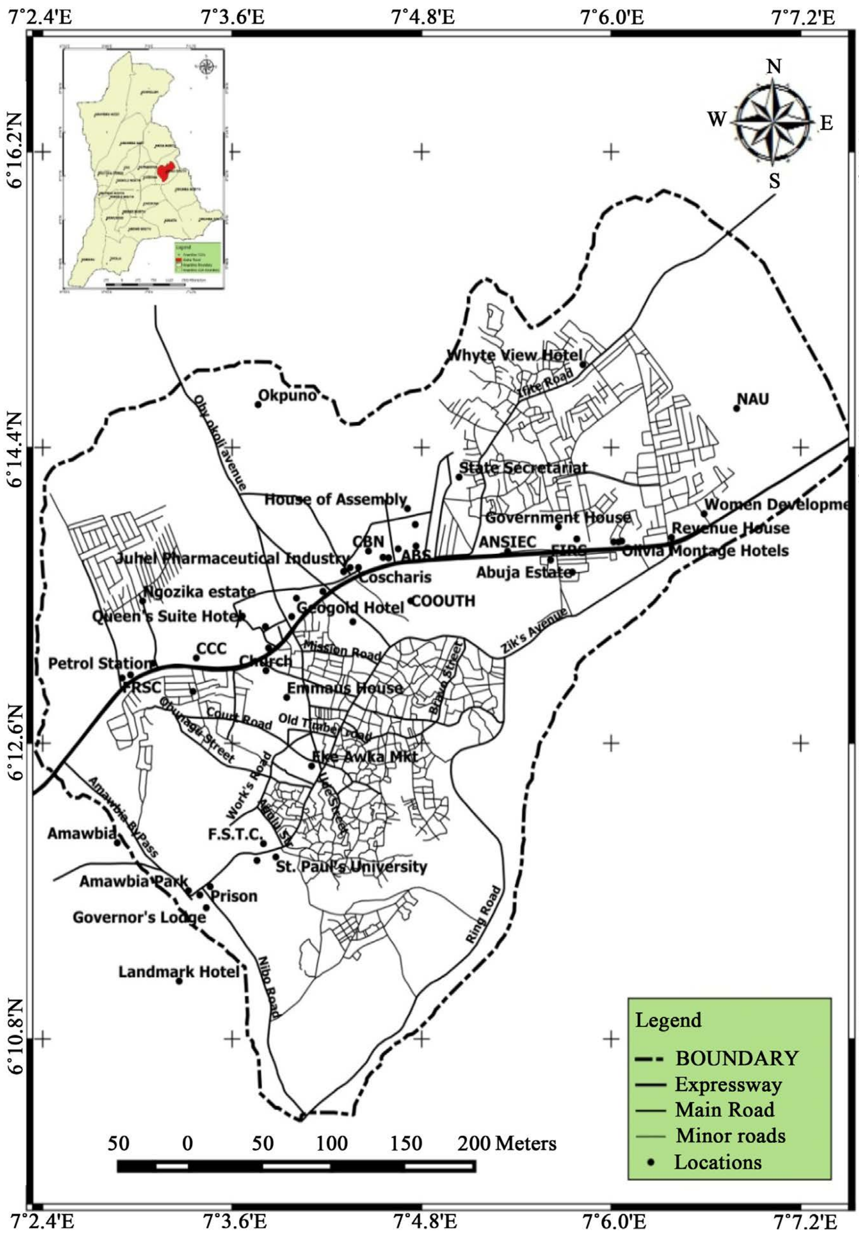


**Figure 1.** Map of Awka town.

The topography is characterized by rugged relief and it lies completely on the Awka-Orlu upland [20]. The climate of Awka falls within the tropic wet and dry type based on Koppen's classification. The rainfall is patterned in such a manner that the long wet season occurs normally from April-October while the dry season occurs from November-March. The mean annual rainfall is about 1805 mm while the maximum and minimum temperatures are 32.1˚C and 23.5˚C respectively. In recent times, the onset and cessation period of the rainfall in the study area has been observed to vary greatly over time.

## 2.2. Data Processing

The Landsat imageries were acquired from the Landsat.org which comprised of the Thematic Mapper (TM), Enhance Thematic Mapper plus ($ETM^+$) image and the Operational land Imager (OLI). The images were acquired to cover 30 years period at an interval of 15 years as shown in **Table 1**. The satellite data have 30 m × 30 m spatial resolutions; the TM, and $ETM^+$ images have spectral range of 0.45 - 2.35 micro meter with bands 1, 2, 3, 4, 5, 6, 7 and 8 while the Operational Land Imager (OLI) extends to band 12 [21]. The first step taken in this study was to define the study area which was achieved using an administrative map showing Awka City boundary. Then image classification and change detection were carried out.

## 2.3. Data Processing

Here, the band compositions which were adopted are bands 2, 3 and 4 for Landsat TM (1986) and $ETM^+$ (2000) and bands 5, 4 and 3 for Landsat OLI/TIRS (2015). A false Colour Composite operation were performed using the IDRISI software and the Landsat bands were combined in the order of band 4, band 3 and band 2 for Landsat TM, ETM and $ETM^+$ while Landsat OLI was composited in the order of band 5, band4 and band 3 due to change in sensor [21]. The False Color Composite was further classified using the Maximum Likelihood Classification Technique [21]. A supervised classification was performed by creating a training sample and based on spectral signature curve [21]; various land use types and cover classes were identified. Six classes were identified and they include:

**Table 1.** Land use/land cover areas of Awka (1986-2015).

| Land Use Classes | Area ($km^2$) | % | Area ($km^2$) | % | Area ($km^2$) | % |
|---|---|---|---|---|---|---|
| Bareland | 0.904 | 1 | 1.359 | 2 | 0.4231 | 1 |
| Built-Up | 9.552 | 16 | 21.31 | 35 | 21.458 | 36 |
| Cultivated Lands | 16.040 | 27 | 16.12 | 27 | 12.823 | 21 |
| Dense Vegetation | 0.834 | 1 | 0.699 | 1 | 0.6310 | 1 |
| Savanna Vegetation | 22.090 | 37 | 12.40 | 21 | 12.483 | 21 |
| Riparian Vegetation | 10.772 | 18 | 8.307 | 14 | 12.368 | 20 |
| TOTAL | **60.2 $km^2$** | **100%** | **60.2 $km^2$** | **100%** | **60.2 $km^2$** | **100%** |

built-up, riparian vegetation, savanna vegetation, dense vegetation, cultivated land and bare land. Changes that occurred over the study period 1986-2015 (30 years) were analyzed. The extents of the land use and land cover changes over the study period were also calculated. The results are presented in maps, charts and tables below.

### 2.4. Retrieving Land Surface Temperature

To derive Land Surface Temperature, the radiometrically corrected Landsat imageries band 3, 4 and the thermal infrared data (band 6) were used. The TM, ETM+ and OLI images were calibrated into the geographic reference system of WGS_1984 and initially calibrated to at-sensor radiance and atmospherically corrected to estimate the surface reflectance using a radiometric calibration technique based on the image header file, solar elevation angle, gain offset and calibration parameters of the image. Thus, the method and procedure utilized in this study involve the conversion of DN to at-satellite brightness temperature, followed by correction for atmospheric absorption, re-emission and surface emissivity which has equally been used in [1] and [22]. The method is further described below:

DN conversion to at radiance is given by the function:

$$L_\lambda = \frac{\left(L_{min} - L_{\max}\right) \times \text{DN}}{255} + \text{Offset} \tag{1}$$

Conversion from radiance to reflectance (Surface albedo) [1]:

$$r_o = \frac{rp - rp_{\min}}{t} \tag{2}$$

where, "$t$" is transmisivity = 0.976204 − 0.08308 $To$ while $To$ is the near surface temperature and $rp$ is the broadband reflectance [1] given as:

$$rp = \frac{\sum \text{ESUN} \times rp(\lambda)}{\sum \text{ESUN}_\lambda} \tag{3}$$

where, ESUN = mean solar exo atmospheric irradiance and $rp(\lambda_1)$ is the planetary reflectance [1] given as:

$$rp(\lambda) = \frac{\pi \times L_\lambda \times d^2}{\sum \text{ESUN}_\lambda \times CosQ} \tag{4}$$

where, $L_\lambda$ = Spectral radiance at the sensor aperture; $D$ = Earth sun distance; $CosQ$ = Solar Zenith angle; $t$ = One way atmospheric transmittance.

The NDVI image was computed for 1986, 2002 and 2015 from their reflectance data using the formula below:

$$\text{NDVI} = \frac{r4 - r3}{r4 + r3} \tag{5}$$

After the image classification of the study area in Landsat 7 ETM$^+$ and Landsat 8, OLI, the land surface emissivity values were derived using Equation (6). Thereafter, the emissivity raster images for the selected periods were generated and used in the conversion of brightness temperature image to Land Surface Temperature (LST) using the Equation (4).

Emissivity,

$$\varepsilon o = 1.094 + 0.047 \times \ln(\text{NDVI}) \tag{6}$$

$$Ta = 16.9684 + 0.90967 To \tag{7}$$

where, $Ta$ is the mean atmospheric temperature as shown in [8].

Effective satellite temperature $T_s$ as implemented in [1] and [8] is given as:

$$T_s = \frac{K_2}{In(K_1/L_\lambda)+1} \tag{8}$$

Therefore, the surface temperature ($T$) can be estimated using this formula:

$$T = \frac{1}{C}\left[\alpha(1-C-D)+\left(b(1-C-D)+C+D\right)T_s - DT_a\right] \tag{9}$$

$$C = t\varepsilon \tag{10}$$

$$D = (1-6)\left[1+t(1-\varepsilon)\right] \tag{11}$$

where $\lambda$ = wavelength of emitted radiance = 11.5 μm [22], $\alpha = hc/k$ ($1.438 \times 10^{-2}$ mK), $k$ = Stefan Boltzmann's constant ($1.38 \times 10^{-23}$ J·K$^{-1}$), $h$ = Planck's constant ($6.26 \times 10^{-34}$ J·s), and $c$ = velocity of light ($2.998 \times 10^{8}$ s$^{-1}$), $a$ = −67.345 and 0.4658 [1].

## 3. Result and Discussion

### 3.1. Land Use/Land Cover Conditions

Land use characteristics in Awka Town, 1986-2015 was determined using TM, ETM$^+$ and OLI imageries of 1986, 2002 and 2015 respectively. Six classes of land uses and cover characteristics were recognized (**Figures 2-4**). The result shown (**Table 1**) indicates that changes had taken place in Awka over the 30 year study period regarding land use and the associated cover characteristics.

The built-up area has been on the increase, expanding from 9.55 km$^2$ in 1986 to 21.3 km$^2$ in 2000 and 21.45 km$^2$ in 2015. Cultivated lands have maintained a steady decline since 2000 having lost about 3.29 km$^2$ of its area. Similarly, vegetation, made up of dense, savanna and riparian, has been on a decline from a total of 33.69 km$^2$ in 1986 to 21.407 km$^2$ losing about 12.29 km$^2$ of its area and increased by a mere 4.07 km$^2$ in 2015. These changes as shown in **Table 1** and **Figures 2-4** imply that the gains witnessed mainly by built-up area and cultivated lands were at the expense of vegetation and other land use classes.

With respect to the vegetation class, the savanna type vegetation was mostly affected losing roughly 16% of its surface are in a space of 15 years (1986-2000) but has maintained a quasi-steady state from 2000 to 2015. Whereas the dense vegetation part maintained its 1% of the total land area of Awka throughout the 30 year period but with slight reduction in actual size.

A steady decline has been observed with the area losing about 0.2 sqkm of its original size from 1986 to 2015. On the other hand, the riparian vegetation produced a different picture given than in the first phase, between 1986 and 2000, 4%

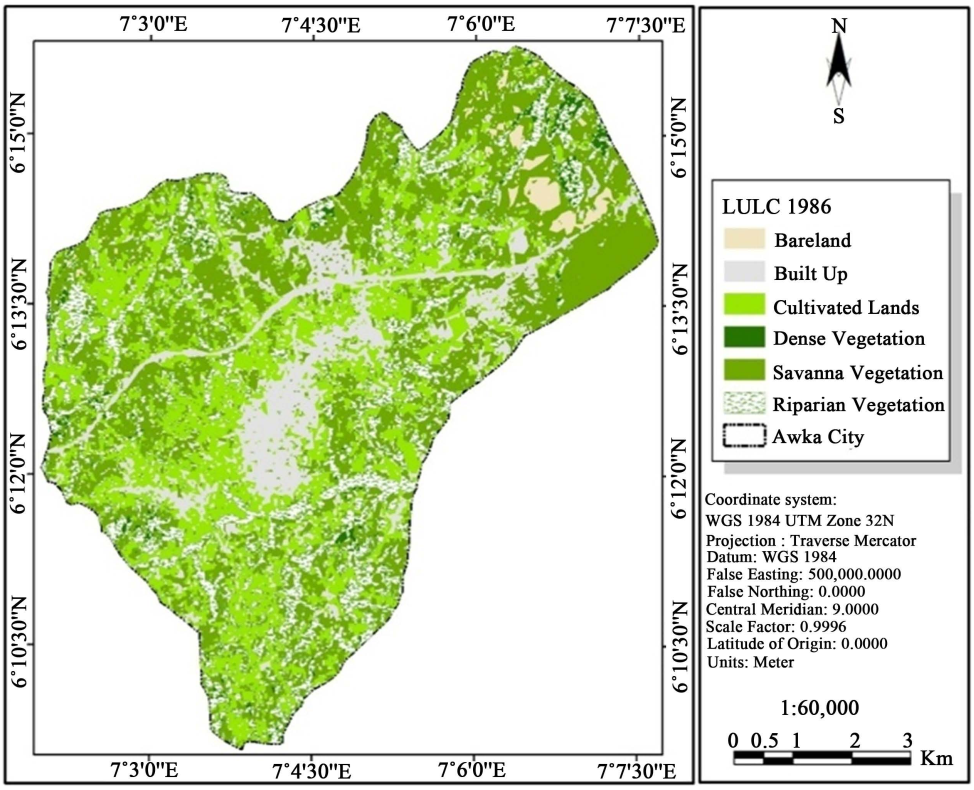


**Figure 2.** Land use/land cover change for 1986.

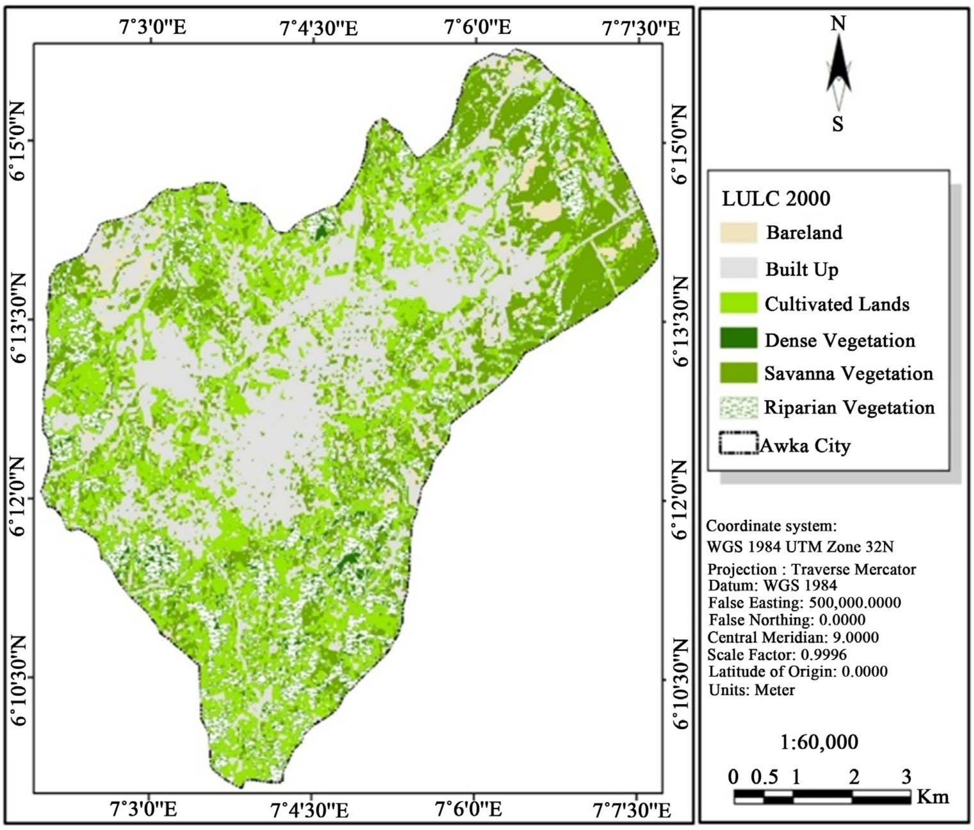


**Figure 3.** Land use/land cover change for 2000.

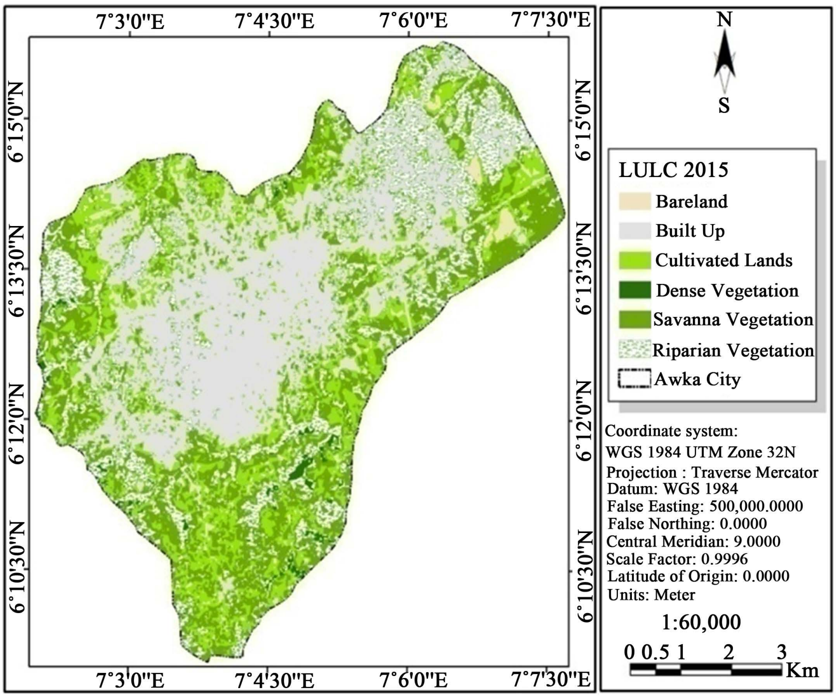


**Figure 4.** Land use/land cover change for 2015.

constituting about 2.5 km$^2$ of its original land coverage in 1986 (10.772 km$^2$) was lost but thereafter expanded by 4.06 km$^2$ (about 6%) to 12.361 km$^2$ by 2015.

Similarly, the bare land maintained its 1% of the total land area in 2015 as at 1986 but with a lesser area in square kilometers despite recording an increase of 1% of the total land area from 1986 to 2000 amounting to about 0.455 km$^2$; between 2000 and 2015, about 0.9357 km$^2$ (even higher than the original land area in 1986) of its land area was lost leaving only about 0.4231 km$^2$ as the total bare land area as at 2015.

On the other hand, the built up area, as mentioned earlier, has maintained a steady increase in its land area; while the change in land area is quite small between 2000 and 2015, it was massive from 1986 to 2000. As shown in **Table 1**, the percentage of the total built-up environment was 16% of the total Awka land area whereas by 2000, it rose to 35% (an increment of 19% of the total land area) and reached the 36% mark by 2015. The cultivated portions of Awka town saw an almost infinitesimal increase in size, recording a mere increase of 0.081 km$^2$ between 1986 and 2000; and losing greatly to either of built-up lands or riparian vegetation about 3.29 km$^2$ of its surface area.

## 3.2. Land Surface Temperature Variations

The thermal infrared band is converted to at spectral radiance and brightness temperature [17]. As reported in similar studies [8] [18], it is quite clear that the highest values of Land Surface Temperature (LST) are in the urban or built-up area and other impervious surfaces while the lower LST values are found around the riparian and dense vegetated areas of Awka. The LST maps (**Figures 5-7**)

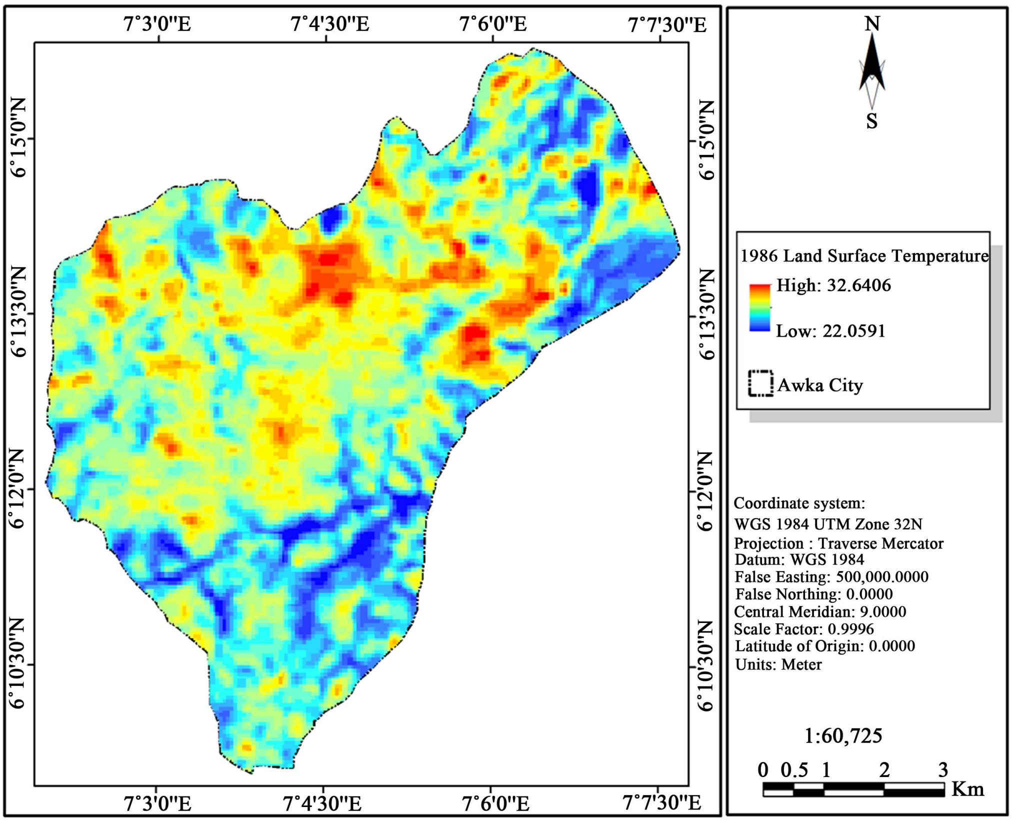


**Figure 5.** Land surface temperature for 1986.

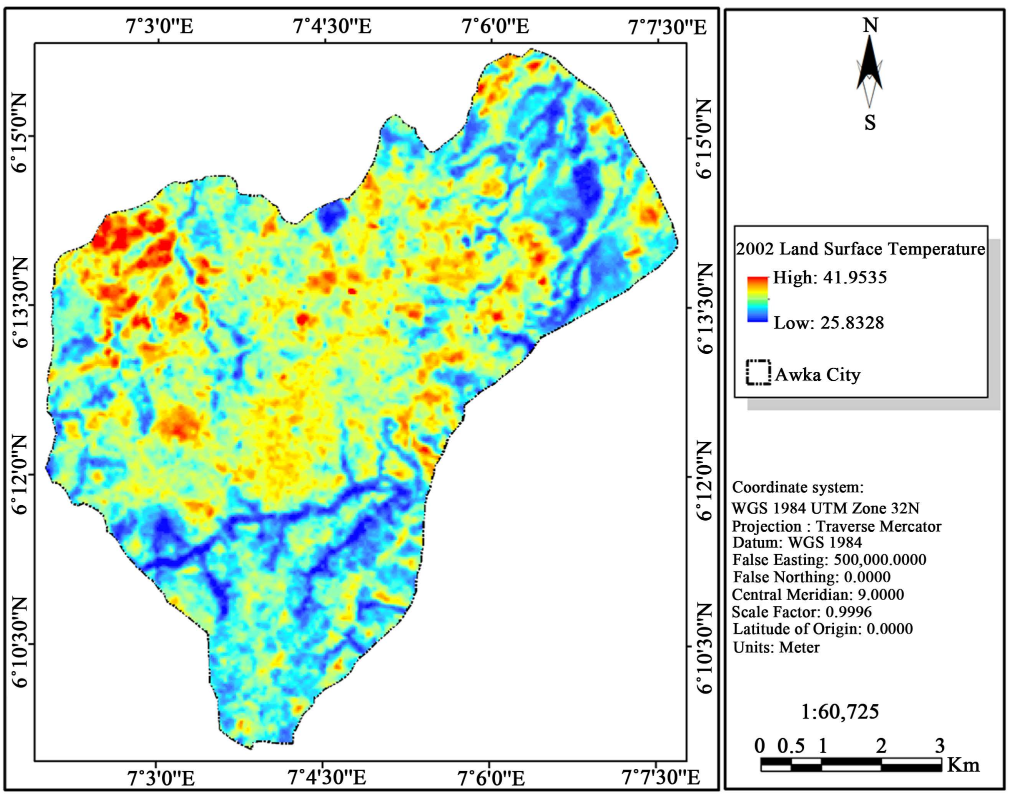


**Figure 6.** Land surface temperature for 2002.

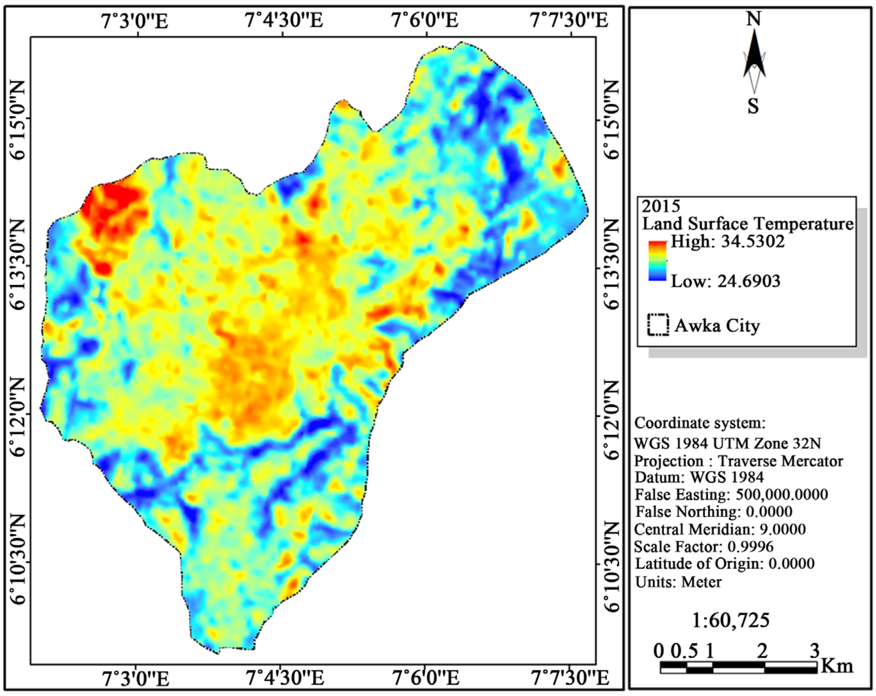


**Figure 7.** Land surface temperature for 2015.

show that the lowest and the highest LST values vary across the three selected periods (1986, 2000 and 2015). The LST map of 1986 shows that the lowest radiant temperature is 22˚C while for 2000 and 2015, it is 25.8˚C and 24.67˚C respectively.

These values are observed for the riparian and dense vegetal areas along ring road, within Nnamdi Azikiwe University, close to Governor's lodge Amawbia etc. and followed by similar low values around Agu-Awka area with savanna type of vegetation. The temperature around the built-up areas and other impervious surfaces [17] such as Alex Ekwueme square, around State House of Assembly, Unizik Temporary site, Arthur Eze avenue, Oby Okoli avenue etc. are shown to have the highest values while the built up surfaces around the riparian vegetated areas like within Nnamdi Azikiwe University, behind Ngozika estate, close to Governor's lodge Amawbia, Okpuno etc. are much lower than the built up areas located farther away from these riparian and dense vegetated areas. Thus in all the years, urban or built-up area exhibit the highest surface radiant temperature, followed by bare land and cultivated areas. The average values of radiant temperature by land use/land cover type [17] in 1986, 2000 and 2015 are summarized in **Table 2**.

This outcome is a clear indication that the increase in impervious surfaces and non-vegetal surfaces such as stone, metal, asphalt and concrete leads to increasing surface radiant temperature [1] [17]. In other words, it shows that land use/land cover changes do have intense effect on the surface radiant temperature of a location and as result, a confirmation of the assertion that land use is the important reason leading to increase in LST [10].

Table 2. Land surface temperatures in degrees Celsius by land cover.

| Land Use/Land Cover Types | Years | | |
|---|---|---|---|
| | 1986 | 2000 | 2015 |
| Built-up | 32.6˚C | 41.9˚C | 34.5˚C |
| Bare land | 30.1˚C | 35˚C | 30.4˚C |
| Cultivated | 28.6˚C | 32˚C | 30˚C |
| Dense | 24˚C | 28˚C | 27.7˚C |
| Savanna | 25˚C | 30˚C | 28˚C |
| Riparian | 22˚C | 25.8˚C | 24.6˚C |
| Mean Surface Temperature | 27.1˚C | 32.1˚C | 29.2˚C |

From this study, the resulting mean surface radiant temperatures for the 1986, 2000 and 2015 are 27.1˚C, 32.1˚C and 29.2˚C respectively. It is apparent from Table 2 that vegetation covers show a considerably low radiant temperature in all the years, because dense vegetation as well as riparian reduces surface temperature through transpiration and evaporation. The result showed that land use/cover changes observed in Awka town are due to alteration of vegetation cover to other land use/cover types within the study period. This alteration had given rise to an average increase of 2.2˚C in surface radiant temperature.

The observed trend in land use change is quite revealing given that the rate of land use change during the period 1986 to 2000 was enormous and indicative of the need for rapid development of Awka town at the time, following the disintegration of the old Anambra into Enugu and Anambra states with Awka as the capital of Anambra state. This period was characterized by intense deforestation and clearing of land for various developmental projects and agriculture which is made evident by the level of increase in observed bare land and built-up areas which are characterized by vegetal removal and the concomitant decrease in total vegetal cover (dense, savanna and riparian vegetations). This rapid depletion of vegetation cover has a wide range of impacts such as in the reduction of the natural cooling effects of shading and evapotranspiration of plants and shrubs [1]. To buttress this fact, [13] reported negative results which they confirmed to exist between LST and normalized difference vegetation index (NDVI) when correlated. This is not far-fetched given that vegetal enclaves act as a sinks within an island of heat because of their cooling effects.

However, the attendant consequence of these land use activities was clearly depicted by the nature of increase experienced in the LST. As shown in Table 2, the LST values for all land use types were highest in 2000 after which the LST values for all land use types have remained higher than the initial 1986 values–a clear indication of reduction in land cover or vegetation covers. However, with vegetation cover depletion owing to urbanization, surface albedo is affected and the resultant impact of this is the tendency towards the development of urban heat island (UHI) effect given that increase in built up area characterized by impervious surfaces is sustained without considering proper conservation practices like greening and reforestation.

## 4. Conclusion

The observed changes in the identified land use/cover types of Awka advocate that urbanization is an important factor responsible for land conversion in the study area. The increase in rate of land use change has its attendant effects on both the environment and the comfort of residents. This has been monitored by various studies using Landsat $ETM^+$ and TM images. The land use/land cover of the study area is classified into six classes: built-up, bare land, cultivated, dense, savanna and riparian. Due to urban growth of Awka City, there have been significant changes in the land use/land cover of the study area. There have been significant decreases in the vegetated areas. The result also shows that LST and thermal signal of built-up areas and barren land has increased the radiant temperature. The vegetative areas can provide positive impacts on regulating high temperature in urban areas. Thus, a greater part of the urban land surfaces should be kept under permanent vegetation cover to minimize the wide range of effects associated with land cover removal. To achieve this, efforts should be made towards planned reforestation, advocating for developers to incorporate tree planting as part of their landscaping activities around such structures and development of parks and botanical gardens within the Awka city. Thus, on the part government and relevant planning agencies and MDAs such as ACTDA, ASHDC etc., adopting policies for regulating the decline of vegetation in the urban land transformation processes should be encouraged and environmental education should be reawakened to achieve the desired sustainable development with respect to environmental resource planning and management [1]. This research is important for urban planning and environmental protection [10].

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